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BULLETIN OF MARINE SCIENCE
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VOLUME 2 1952 NUMBER 1

NOTES ON MARINE MIDGES FROM THE EASTERN UNITED STATES (DIPTERA, TENDIPEDIDAE [= CHIRONOMIDAE])

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ABSTRACT

The attention of invertebrate zoologists and seashore collectors is invited to the opportunities afforded by the Clunionine midges as materials for general distributional and ecological studies. As an example of distributional problems in this group, *Telmatogeton japonicus* Tokunaga, a midge previously known only Japan and Hawaii, is recorded from New York and Florida. Descriptions and figures are given of the immature stages of *Thalassomya bureni* Wirth, with brief notes on the biology of this species in Florida.

The marine midges of the subfamily Clunioninae (family Tendipedidae) are a small taxonomic group, world-wide in distribution, with a fair proportion of large and small, widestpread and restricted genera. They show promise of providing excellent material for extensive distributional and ecological studies, but such work has been greatly hindered by the infrequency with which they have been collected in most parts of the world, in spite of their abundance along rocky seacoasts. For example, on subantarctic and antarctic coasts the genera *Belgica* and *Halirytus* are common and very characteristic forms of intertidal invertebrate life, but in the many zoological accounts of the expeditions to this part of the world these midges are seldom mentioned.

Our knowledge of intertidal insects in general has suffered greatly because of a lamentable failure of entomologists and general invertebrate zoologists to consider their fields as closely related, or to exploit their common interests in the distribution and ecology of intertidal animals. It is the purpose of these notes, therefore, by publishing extensions of the range of *Telmatogeton japonicus* and describing the immature stages of *Thalassomya bureni,* to call the attention of sea-

shore collectors to this common and interesting group of insects with the hope of stimulating their collection and the publication of new findings.

New Records Extending the Range of Distribution of *Telmatogeton japonicus* Tokunaga

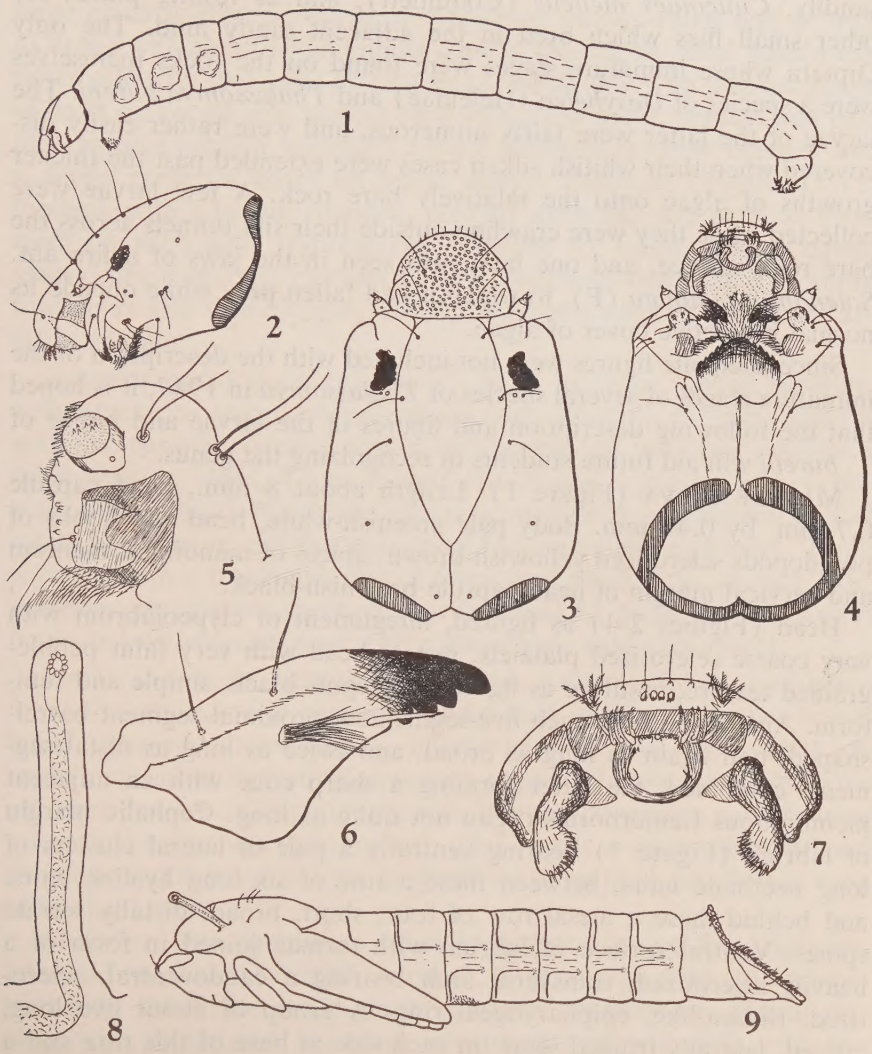
This marine midge was described from the coasts of Japan (Tokunaga, 1933) and has more recently been reported from Hawaii (Wirth, 1947). A large series of males and females of this species has been received in collections from a light trap operated durnig 1949 and 1950 at the U. S. Bureau of Fisheries station on Santa Rosa Island near Pensacola, Florida. A number of specimens of *T. japonicus* from Long Island, New York, have also been received from Dr. William F. Buren, who took them in July 1949 in a light trap operated at the Idlewild Airport on Jamaica Bay. All of these specimens agree well with Tokunaga's description of *T. japonicus* and with material of this species collected in Hawaii by the author.

T. macswaini Wirth, a close relative and the first known North American representative of the genus, was described a short time ago from the coast of California (Wirth, 1949). No species of *Telmatogeton* was known from any Atlantic coasts until the recent work of Oliveira (1950) in which two new species were described from Brazil. The Brazilian species possess a remarkable bifid empodium similar to that found in *T. pacificus* Tokunaga, and are typical members of the group of species related to *T. simplicipes Edwards,* previously known only from Pacific shores.

The Immature Stages of *Thalassomya bureni* Wirth

This species was described (Wirth, 1949) from specimens collected by Dr. Buren at light on Fisher's Island, Miami Beach, Florida, in 1947. On a collecting trip to Palm Beach County, Florida, in August 1951, the author was successful in locating the immature stages of *T. bureni* and in taking additional adults.

At the mouth of the Boynton Canal which flows into Lake Worth across from the South Lake Worth Inlet near the town of Boynton Beach, Florida, there is a sandy, intertidal, mud flat on which are located a few scattered blocks of stone. These were covered with a growth of green algae, mostly *Enteromorpha,* which in August 1951 was sadly depleted by the hot and relatively dry summer weather. These rocks formed focal points for the mating of the tiny, yellow



IMMATURE STAGES OF THALASSOMYA BURENI

Figure 1, Larva, side view; Figures 2-4, Head of larva, enlarged; Figure 2, Lateral view; Figure 3, Dorsal view; Figure 4, Ventral view; Figures 5-7, Larval mouthparts, enlarged; Figure 5, Left maxilla, ventral view; Figure 6, Right mandible, dorsal view; Figure 7, Labrum and associated structures, ventral view; Figure 8, Pupa, right respiratory organ, dorsal view; Figure 9, Pupa, lateral view.

sandfly, *Culicoides melleus* (Coquillett), and as resting places for other small flies which bred in the adjacent sandy mud. The only Diptera whose immature stages were found on the rocks themselves were a species of *Dasyhelea* (Heleidae) and *Thalassomya bureni*. The larvae of the latter were fairly numerous, and were rather easily discovered when their whitish silken cases were extended past the thicker growths of algae onto the relatively bare rock. A few larvae were collected while they were crawling outside their silk tunnels across the bare rock surface, and one larva was seen in the jaws of a fire ant, *Solenopsis geminata* (F), to which it had fallen prey while outside its normal protective cover of algae.

Since adequate figures were not included with the description of the immature stages of several species of *Thalassomya* in 1947, it is hoped that the following description and figures of the larvae and pupae of *T. bureni* will aid future students in recognizing the genus.

MATURE LARVA (Figure 1). Length about 8 mm., head capsule 0.7 mm. by 0.46 mm. Body pale greenish-white, head and hooks of pseudopods sclerotized yellowish-brown; apices of mandibles, mentum and cervical margin of head capsule brownish-black.

Head (Figures 2-4) as figured, integument of clypeolabrum with very coarse sclerotized platelets, rest of head with very faint pebble-grained texture; vestiture as figured. Eyespots black, simple and reniform. Antennae short, each five-segmented, proximal segment barrel-shaped, half again as long as broad, and twice as long as distal segments combined, the latter forming a sharp cone with an adjacent membranous Lauterborn's organ not quite as long. Cephalic margin of labrum (Figure 7) bearing ventrally a pair of lateral clusters of long pectinate hairs, between these a row of six long hyaline hairs, and behind these a mesal row of four, short, broad, distally serrate spines. Ventral surface of labrum with tormae joined in form of a heavily sclerotized, transverse arch bearing a caudoventral, sclerotized, ribbon-like, epipharyngeal ring. A group of about five long, curved, laterally-fringed setae on each side at base of this ring and a submedian pair of very low, broad, distally-toothed spines just behind arch of torma. Premandibles (Figures 2, 7) each articulating at dorsal or proximal end with end of torma, rather flattened and spatulate, the distal ends bearing a distro-lateral, fringed membrane. Mandibles (Figure 6) each with four blunt distal teeth on posterior margin with an appressed, hyaline spine just basad; a compact brustia of about ten long hairs midway on ventral surface; outer convex side with two long

setae. Maxillae (Figure 5) each flattened and membranous, with a large basal sclerotized cardo, a cylindrical palpus about half as high as broad with about seven minute conical sensilla on distal membrane; outer side with two pairs of long setae, mesal side with a dense fringe of hairs on dorsal side, almost bare with a few short, conical and peg-like, hyaline sensilla ventrally; a long, flattened, hyaline filament and a dense, posterior beard on mesal margin. Mentum (Figure 4) 11-toothed, with a broad, rounded, median tooth and five narrow, blunt teeth on each side. Hypopharynx (Figure 4) ovoid, with a dense, ventral beard of long, laterally-fringed, yellowish hairs and a group of four short and three longer, distally branched hairs in middle of anterior margin.

Anterior pseudopods (Figure 1) fused at bases, apices separate, with numerous sharp, curved spines with minutely fringed, concave margins, densely covering apices and lateral and posterior margins a third way to bases. Thoracic and abdominal segments with a few ventrolateral hairs. Ninth abdominal segment with a sublateral pair of rather small hairs, not borne on papillae, on caudal extremity. Tenth segment with a transverse row of three very small setae on each side; posterior pseudopods short, each with about 11 large, curved, simple hooks in two irregular rows with a mesal gap; anal gills absent.

PUPA (Figure 9). Length about 5 mm.; subcylindrical, integument of cephalothorax and terminal abdominal disc with amber-brown pebble-grained sclerotizations, nearly bare, a few, small setae on cephalothorax as figured. Respiratory organs (Figure 8) subcylindrical, dark brown, arising on each side in humeral region; each bearing a terminal spiracular opening with 10-12 rays, a short, differentiated chamber about twice as long as diameter of spiracle just before apex of tracheal trunk.

Abdomen with prominent black U-shaped lines on first eight tergites and on second to eighth sternites; third sternite with a prominent brownish, transverse ovoid patch of coarse shagreening. Eighth segment with roughened, brownish integument, on each side with two setae at the ends of the transverse suture of terminal disc, three fine setae at bases of genital lobe and a pair of long setae under rim of disc. Terminal disc quite oblique, face ovoid, about 0.8 times as broad as long, divided at upper fourth by a dorsally arched transverse suture. Rim of disc above suture with fine denticles, face of this portion of disc with very coarse, plate-like thickenings, without setae. Rim of disc below suture with denticles in groups of two to four, each bearing

long, amber hairs; face of this portion of disc with heavily sclerotized platelets on a median triangular area with apex caudad, and bearing two sublateral pairs of long setae.

The larvae of *T. bureni* may be distinguished from those of other known species of *Thalassomya* by the short antennae, four-toothed mandibles, 11-toothed mentum, fringed spines of the anterior pseudopods and 11 hooks on each posterior pseudopod, while *T. setosipennis* Wirth differs in having five to six-toothed mandibles, simple spines on the anterior pseudopods and 14-15 hooks on the posterior pseudopods, and *T. frauenfeldi* Schiner has the antennae much longer, seven-toothed mandibles, 15-toothed mentum, longer maxillae, simple spines on the anterior pseudopods and about 15 hooks on the posterior pseudopods.

The pupae of *T. bureni* are distinguished by the cylindrical respiratory organ with apical spiracle, the transverse oval shagreened patch on the third abdominal sternite and face of upper sclerite of terminal disc with only a pair of setae near rim; *T. setosipennis* differs in having the shagreened patch on the third sternite longer than broad and six hairs just inside rim on face of upper sclerite of disc; while *T. frauenfeldi* has the respiratory organ horn-shaped with spiracle at basal third, the third sternite as in *T. setosipennis,* and face of upper sclerite of disc without hairs, and *T. maritima* Wirth has heavily shagreened subapical patches on each abdominal segment and the face of upper sclerite of disc is without hairs.

REFERENCES

OLIVEIRA, S. J. DE

1950. Sôbre duas novas espécies Neotrópicas do gênero *Telmatogeton* Schiner, 1866 (Diptera, Chironomidae). Mem. Inst. Oswaldo Cruz, *48*:469-485.

TOKUNAGA, M.

1933. Chironomidae from Japan (Diptera) I. Clunioninae. Philippine J. Sci., *51*:87-99, 2 plates.

WIRTH, W. W.

1947. Notes on the genus *Thalassomya* Schiner, with descriptions of two new species (Diptera: Tendipedidae). Proc. Hawaiian Ent. Soc., *13*: 117 139.

1949. A revision of the Clunionine midges with descriptions of a new genus and four new species (Diptera: Tendipedidae). Univ. Calif. Publ. Ent., *8*:151-182, 7 figs.

VARIATIONS IN THE ATLANTIC WIND STRESS VORTICITY[1]

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ABSTRACT

The regional distribution of the vorticity of the wind stress for different months has been computed for the Atlantic Ocean. The variations in the intensity of the Subtropical Gyre and in the locations of the zero-lines between negative and positive vorticity areas have been compared with the annual cycle of the charted surface current in the Straits of Florida. It appears probable that the annual variation in the intensity of the negative vorticity of the Subtropical Gyre, together with the S-N movement of the positive vorticity area, south of the former, are responsible for the annual variation in the strength of the current.

According to a recent paper by Munk (1950), permanent ocean currents are related to the rotational component of the wind stress field over the ocean. The data on wind stress found in SIO Oceanographic Report No. 21, 1950, appear to have been prepared originally for Munk's investigation, and from them he has been able to draw his conclusions by theoretical means. The present study of variations in the Atlantic wind stress vorticity is also based upon these mean wind stress compilations. It is worthwhile mentioning that when applying the theory that shear of wind stress is the fundamental factor in the production of variations in the distribution of current transport, sources of error are admitted in addition to those already present in the charts of wind distribution. The principal one of these is the uncertainty of the drag coefficient for wind speeds less than Beaufort force 4, as pointed out by Munk (1950).

The regional distribution of the vorticity of the wind stress,

$$\zeta = \frac{\partial \tau_y}{\partial x} - \frac{\partial \tau_x}{\partial y}$$

is computed for every month of the year. Also the mass transport through the Straits of Florida seems to show an annual cycle, as pointed out by Iselin (1940), and Hela (1952), and others. According to the charted surface currents, the maxima appear in July and March, the minima in November and April. Calculations based on the sea-level difference between Cat Cay and Miami Beach show identi-

1 Contribution No. 72 from The Marine Laboratory, University of Miami. These studies were aided by a contract between the Office of Naval Research and the University of Miami.

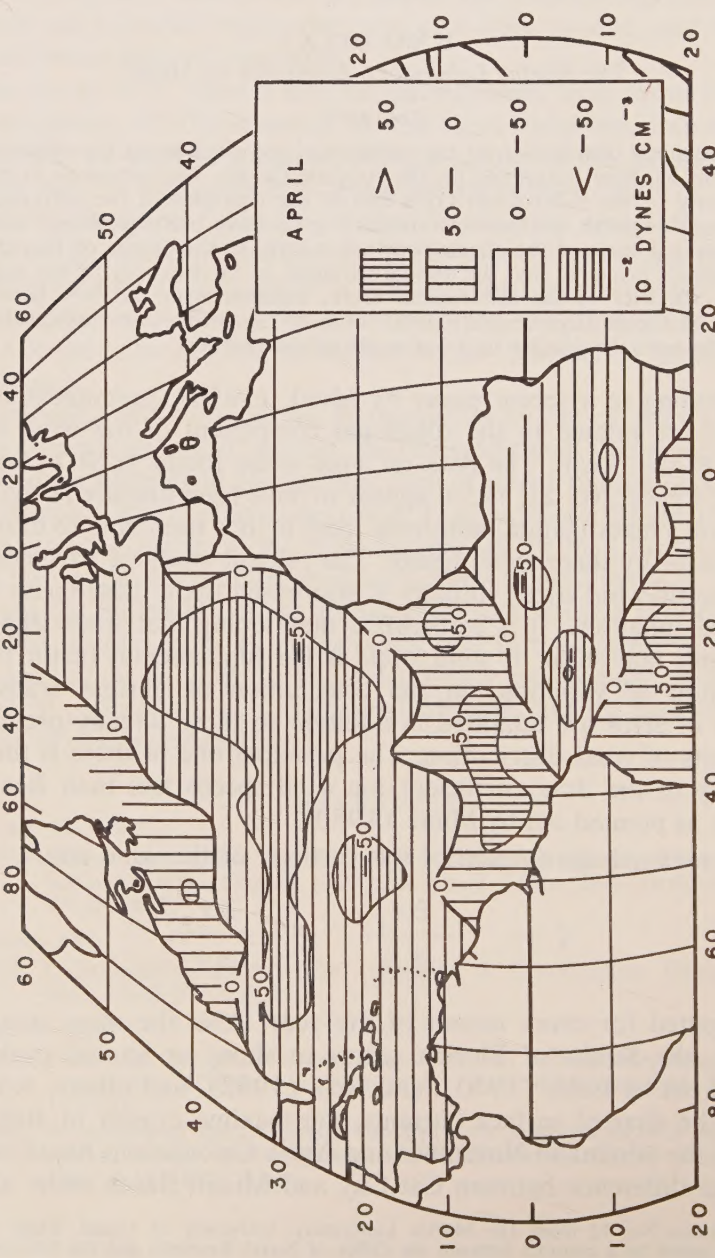

FIGURE 1. Regional distribution of the vorticity of wind stress in April.

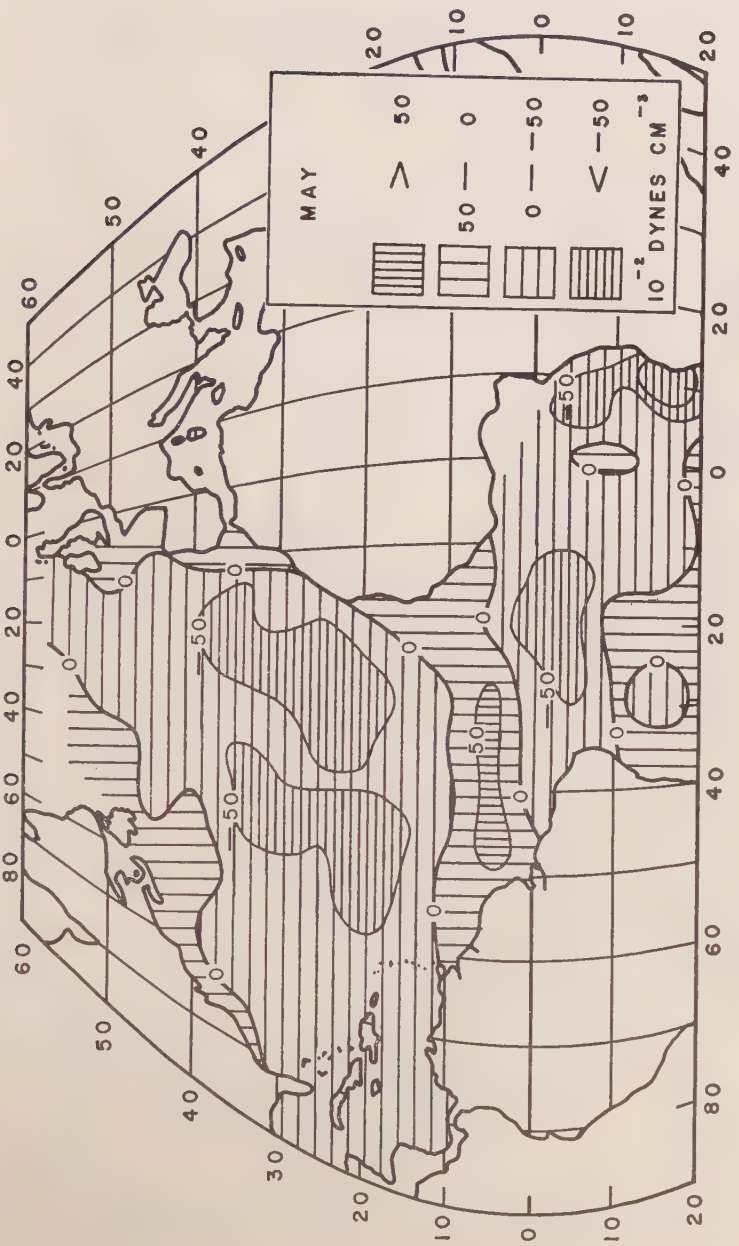

FIGURE 2. Regional distribution of the vorticity of wind stress in May.

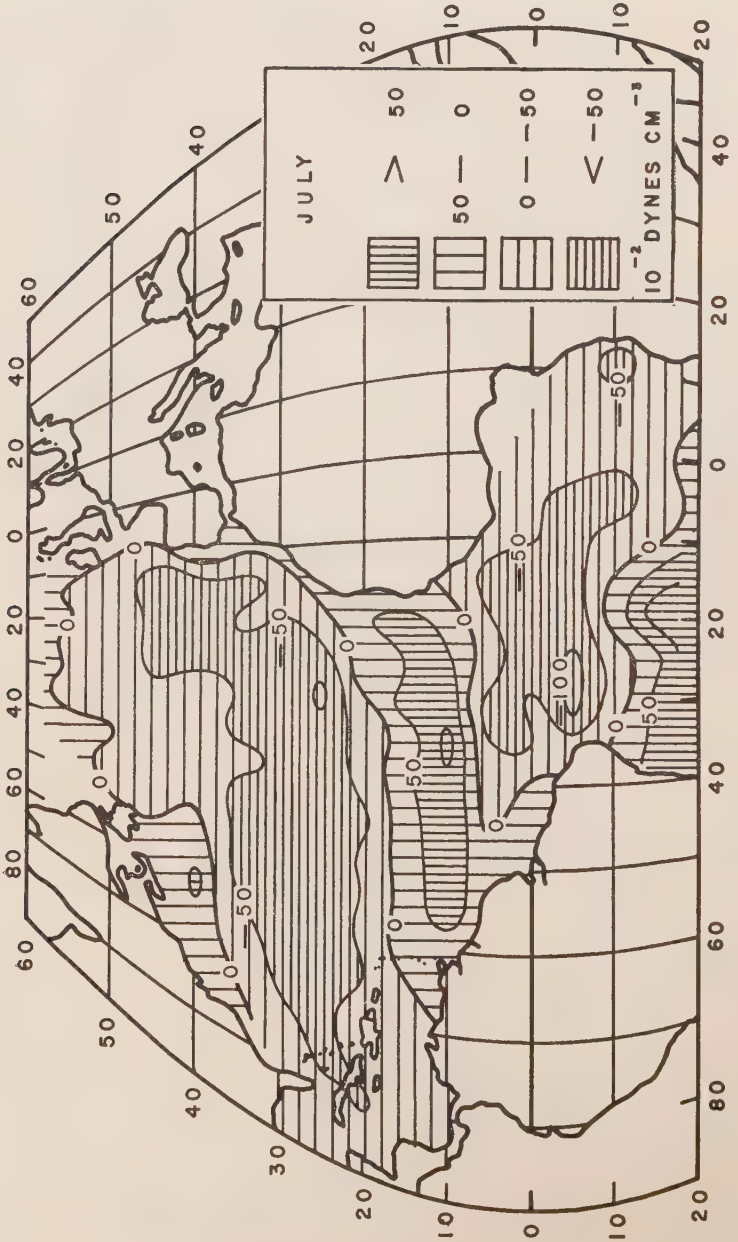

FIGURE 3. Regional distribution of the vorticity of wind stress in July.

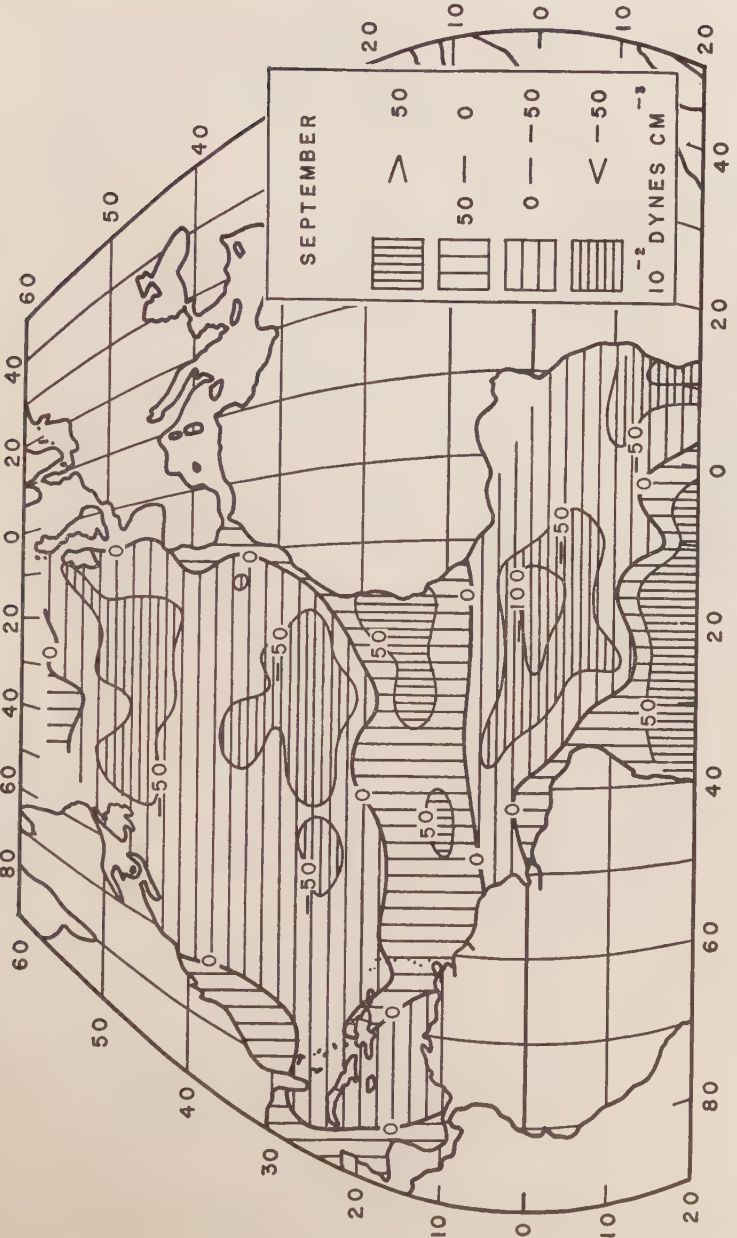

FIGURE 4. Regional distribution of the vorticity of wind stress in September.

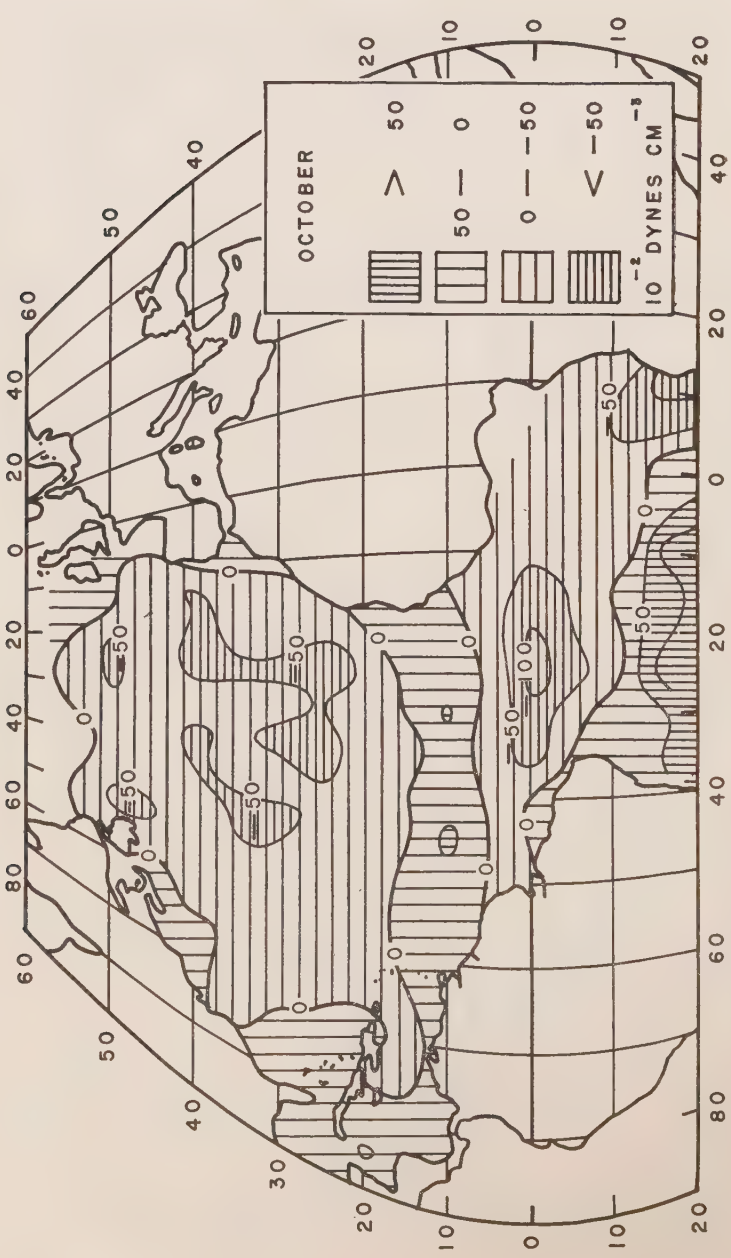

FIGURE 5. Regional distribution of the vorticity of wind stress in October.

cal primary maximum and minimum but the secondary maximum seems to appear in April and the secondary minimum in May. The regional distributions of the vorticity of the wind stress for April, May, July, September, and October are reproduced as Figures 1-5, which are based upon the mean vorticity values, given in 10^{-2} dynes x cm^{-3}, for every five degree quadrangle. There are several details in the annual march of the vorticity which are worthwhile mentioning.

The northern border of the large area of negative vorticity of the North Atlantic unfortunately cannot be determined owing to the lack of wind observations from the northernmost portion of the area. However, it seems probable that the zero-line between the area of negative vorticity, corresponding to the "Subtropical Gyre" of Munk, and the area of positive vorticity, corresponding to the "Subpolar Gyre" has in its northeasterly section a more northerly course during the months of November, January, February, March, April, and May than during the rest of the year. Up to the 50th or 45th longitude the zero line, in its northwesterly section, seems to follow the course of the Gulf Stream very closely, except during September and October. At this longitude the zero line first of all curves to the north and then, usually near Newfoundland, to the east again.

An examination of annual changes in the above large area of negative vorticity, corresponding to the Subtropical Gyre, reveals various types of fluctuations, both in the intensity and in the location of its borders. Perhaps one of the most important details is the occurrence of a regional maximum of negative vorticity in the Sargasso Sea[2] and its disappearance (Figure 5) during October at a time when the speed, and probably also the mass transport of the Florida Current have their minima. For our purpose, however, the most interesting detail is the annual march of the average value of the negative vorticity within a zonal band between latitudes 25°N. and 30°N. extending from the American shore to the European shore, thus roughly corresponding to the location of the centre of the Subtropical Gyre. In Figure 6 the annual march of the above negative vorticity and the annual march of the charted surface current of the Florida Straits are given. Munk (1950) has already suggested " . . . ocean currents might represent a convenient method of obtaining time averages of atmospheric circulation. For example, the intensity of the Gulf Stream (perhaps estimated from tide records) could be related to the

2 The existence and the changes in the intensity of the Sargasso vorticity maximum cannot be seen clearly in the small scale Figures 1-5.

mean wind vorticity in the region of subtropical anticyclones over the Atlantic." In our case the rather close simultaneity of the maxima and minima is evident. At the same time, the following distinct discrepancy between the marches should be noted.

From November to March the speed of the Florida Current is on an average about 5 miles per day weaker than would be expected from the intensity of the vorticity. From April to September the speed of the Florida Current is on an average about 5 miles per day stronger than the intensity of the vorticity would demand. In comparison with this speed, which is equivalent to about 10 centimeters per second, it

TABLE I

THE MONTHLY RESULTANT WINDS OVER THE FLORIDA STRAITS

Month	*Direction of Wind*	*Beaufort*	*Month*	*Direction of Wind*	*Beaufort*
January	30°	1.0	July	150°	1.0
February	20°	1.0	August	130°	1.0
March	50°	0.9	September	80°	1.7
April	70°	0.8	October	45°	2.0
May	100°	1.2	November	40°	2.0
June	150°	1.4	December	30°	1.5

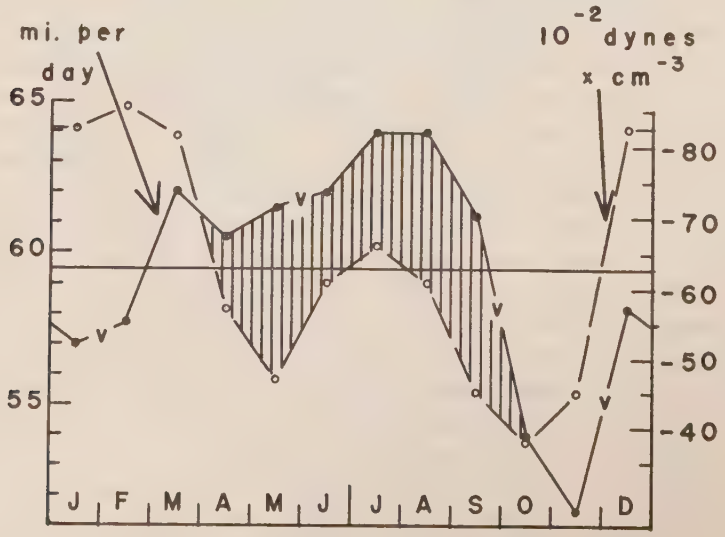

FIGURE 6. Annual march of the charted surface current in the Straits of Florida (solid line) compared with annual march of the intensity of the negative vorticity of the Subtropical Gyre (dashed line).

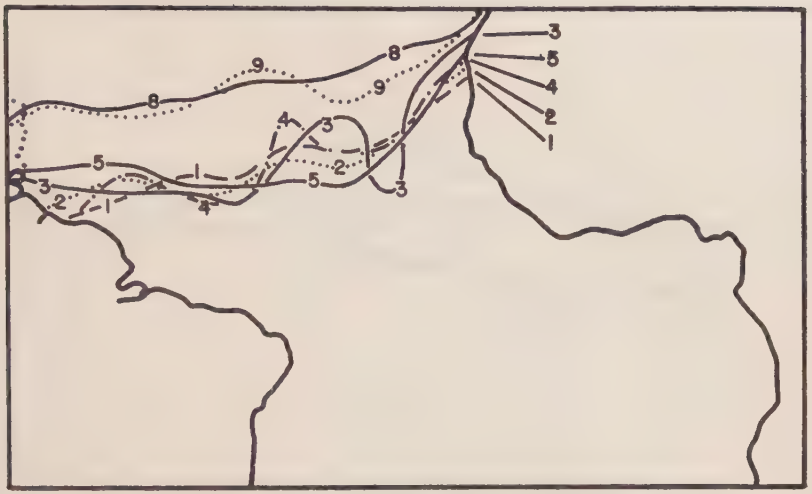

FIGURE 7. Extreme positions of the northern border of the area of positive vorticity. Numbers refer to months of the year.

is worthwhile mentioning that the standard deviation of the charted monthly surface currents is 8 centimeters per second. The monthly resultant winds over the Florida Straits vary as given roughly in Table I. These resulting local winds undoubtedly influence the surface currents, although the winds are so weak that the probable value of the standard deviation of the pure drift current brought about by them is less than 2 centimeters per second. For this reason it is considered unlikely that the local winds are entirely responsible for fluctuations in the Florida Current, or for the discrepancy between vorticity-current relationship considered above.

It is not impossible that the above discrepancy could be partly explained by the annual change in the intensity of the Antilles Current, but that current is, unfortunately, poorly known. The main reason for the discrepancy (Figure 6), however, must be found elsewhere. Reference to Figures 1-5 shows that the locations of the area of positive vorticity between the northeast trade winds and the doldrums varies considerably during the course of the year. The variations for the northern border[3] of the positive vorticity area (Figure 7) are roughly as follows:

(a) It remains at its southernmost position from January to May (*cf.* Figure 1), when it follows approximately a straight line from the

[3] The area east of the Caribbean Sea only has been considered.

FIGURE 8. Extreme positions of the southern border of the area of positive vorticity. Numbers refer to months of the year.

point 8°N., 60°W. to 13°N., 25°W. It is located not more than about 500 km. northwards from the average border between the northeast trade winds and doldrums.

(b) It moves northwards during the period from May to August, on an average about 950 km.

(c) It remains at its northernmost position only a short time in August and September (*cf.* Figure 4), when it roughly follows a straight line from the point 17°N., 60°W. to 21°N., 25°W. It follows rather closely the average center of the northeast trade wind region.

(d) It moves southwards about 950 km. during the period from September to January.

For the southern border of the positive vorticity area (Figure 8) the variations are roughly:

(a) It remains at its southernmost position from January to April (*cf.* Figure1), along a straight line from the point 2°S., 35°W. to 4°N., 15°W. It is located about 400 km. northwards from the average border between the doldrums and the southeast trade winds.

(b) It moves northwards during the period from April to August. Near the African coast it moves about 350 km., at the 35th longitude about 900 km., while its western portion moves still further.

(c) It remains at its northernmost position from August to October (*cf.* Figure 4) along a straight line from 6°N., 35°W. to 7°N., 15°W.,

thus following very closely the average border between the northeast trade winds and the doldrums.

(d) It moves southwards during the period from October to January to its southernmost position.

It was shown in connection with Figure 6 that the mean speed, and probably also the mean mass transport of the Florida Current from November to March are apparently weaker and from April to September stronger than can be accounted for by the intensity of the negative vorticity alone. It can be seen that the northwards movement of the positive vorticity area roughly corresponds in time to the "too strong" speed of the Florida current and the southwards movement of the same area corresponds to the "too weak" speed of the Florida current. Therefore, it appears that an interesting new factor enters, namely the S-N movement of the positive vorticity area, south of the negative vorticity of the Suptropical Gyre. This is apparently partly responsible for the annual variation in the strength of the current, together with the even more important annual variation in the intensity of the latter vorticity. These seem to offer a working hypothesis for a satisfactory meteorological explanation of the annual fluctuation of the Florida Current. This question is being given more detailed attention.

REFERENCES

Hela, Ilmo

1952. The fluctuations of the Florida Current. Bull. Mar. Sci. Gulf & Caribbean, *1* (4): 241-248.

Iselin, C. O'D.

1940. Preliminary report on long-period variations in the transport of the Gulf Stream System. Pap. Phys. Oceanogr. Meteorol., *8* (1): 1-40.

Munk, Walter H.

1950. On the wind-driven ocean circulation. J. Meteorol., *7* (2): 79-93.

THE POST-LARVAL STAGES OF THE SPINY LOBSTER *PANULIRUS ARGUS*[1]

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Abstract

Post-larval stages of the spiny lobster found along the shore at Miami, Florida are identified as *Panulirus argus*. The first 11 post-larval stages are described from animals reared in the laboratory. Length measurements indicate that young lobsters of 17 mm. attain an overall length of 50 mm. during the first year.

Introduction

The phyllosoma larva of the Scyllaridae characteristically metamorphoses to a post-larval form known as puerulus. There is a profound transformation at metamorphoris from the flat, leaflike phyllosoma to the transparent first post-larval stage which closely resembles the adult lobster. Because of the differences between the larval, post-larval and adult stages of the Scyllaridae there was some confusion among early naturalists as to the taxonomic position of these animals. Leach (1817) gave the phyllosoma larvae the status of a genus. The name puerulus was first used by Ortmann and given the status of a genus on the basis of his studies on the post-larval stages of Palinurans (Calman, 1909). It was not until 1914 that Bouvier demonstrated in *Palinurus vulgaris* the transformation of the phyllosoma to the puerulus.

In the Miami area the pueruli first make their appearance in shallow water about the beginning of January. It has been suggested by Gurney (1942) and others that the puerulus might be a free-swimming stage. Gurney reported that numerous specimens of the puerulus of *Jasus* were taken in plankton hauls far out to sea. However, only a single specimen of *Panulirus argus* has been taken in plankton hauls in the Gulf Stream off Miami and it seems certain that this stage is not normally planktonic.

This paper completes the description of the larval and post-larval stages of *Panulirus argus*. The phyllosoma larvae have been described by Lewis (1951). The collection and rearing of material was begun in 1950 by Babis and Moore and was continued by Lewis and Moore in 1951.

There is no doubt that the specimens described herein are the post-

1 Contribution No. 73 from The Marine Laboratory, University of Miami.

larval stages of *Panulirus argus*. The presence of a flagellum on the third maxillepede, the broken transverse furrows on the abdominal tergites and the long antennular flagellum are three of the chief diagnostic features of the species (Smith, 1948). Stage 3 post-larvae possessed these three characteristics while later stages developed the characteristic color of the species. In the first two stages the diagnostic features had not as yet developed but as a number of specimens of these stages passed through successive moults to an identifiable stage they too could be identified as *Panulirus argus*.

The work was supported in part by funds from the Florida State Board of Conservation. The authors wish to express their thanks to Mr. Lawrence Isham for his cooperation in the collections necessary for the present paper, to Mr. Reuben Lasker who kindly supplied the cultures of ciliates, bacteria and diatoms and to Dr. C. P. Idyll for his criticism of the manuscript.

Collection, Rearing and Habits.

The bulk of the specimens on which the present study is based were collected from the wooden panels hung from the side of a floating laboratory of the University of Miami Marine Laboratory near Miami Beach. The post-larval stages gathered on these panels in considerable numbers and were found clinging to clusters of algae, in crevices and underneath the profuse growth of fouling organisms. The small adults were removed to the laboratory for rearing. Freshly metamorphosed post-larval stages and stages up to two inches in length were reared each in a separate 250 ml. beaker of sea water. Larger specimens were reared in larger plunger jars. All jars and beakers were aerated with a stream of air from a small pump. Half the water in each container was changed once a week and any sludge which had collected on the bottom of the container was siphoned off. One valve of an oyster shell was placed in each vessel to provide shelter for the animals.

The animals were fed daily with bits of fresh snail (*Littorina angulifera*). Young stages were also supplied with a few drops of a mixed culture of algae, bacteria and ciliates but it is not known whether they ate it. Any uneaten material was removed at subsequent feedings.

The behaviour of the young lobsters proved to be interesting. The first three stages especially showed a pronounced aversion to light. During the daytime they remained clinging to the underside of the oysters, leaving only at night to feed. Older stages also appeared to prefer the dark but lived satisfactorily if no shelter was available.

The older stages became quite accustomed to being fed and learned to rise to the surface for bits of food held just out of reach. While the food was usually crushed, it was found that specimens of four or five inches were quite capable of crushing the shell with their mandibles and extracting the animal within.

Mortality was heavy among the smaller stages. The greatest mortality occurred at the time of moulting, when the animals appeared unable to free themselves completely from the old exoskeleton. The first moult, from the puerulus stage to the second stage, appeared to be the most difficult. A considerable number of specimens were reared for a period of two or three months while one specimen was kept alive for over six months.

Description of the Stages

Stage 1. Figures 1A, 2A-F, 3D and I.

This is the so-called puerulus stage. It is perfectly transparent when freshly metamorphosed except for the dark eyes and a pair of red pigment spots on the thorax. However, shortly prior to the first moult, several color changes were observed.

The eyes, which are light yellow at first, darken to brown and become almost black. After the eyes have darkened, a pinkish tinge develops on the three basal segments of the antennae. In a few days two pinkish stripes develop on the thorax and abdomen, one on either side of the mid-dorsal line. These gradually deepen to brown and in about a week the legs become banded with alternate stripes of yellow and brown while the three basal segments of the antennae and the dorsal stripes become light brown. The antennae gradually become colored with pink and brown while the rest of the body becomes tinged with shades of purple and brown. Actually these colors belong to the second stage because the moulted skin of the puerulus stage is perfectly transparent. Thus the color changes take place on the newly forming exoskeleton of stage two.

The carapace of the puerulus lacks the grooves and most of the spines of the mature adult. Except for the few spines at the anterior end, the dorsal surface of the carapace is smooth and curves gradually down to the lateral edges. The principal (ocular) spines project forward over the base of the eye-stalks. They are sharpened at their tips but do not project sharply upwards from the carapace as in the adult. Immediately behind them is a smaller pair of spines which project over the bases of the ocular spines. A little to the outside of this second pair of spines is another pair and behind these are a

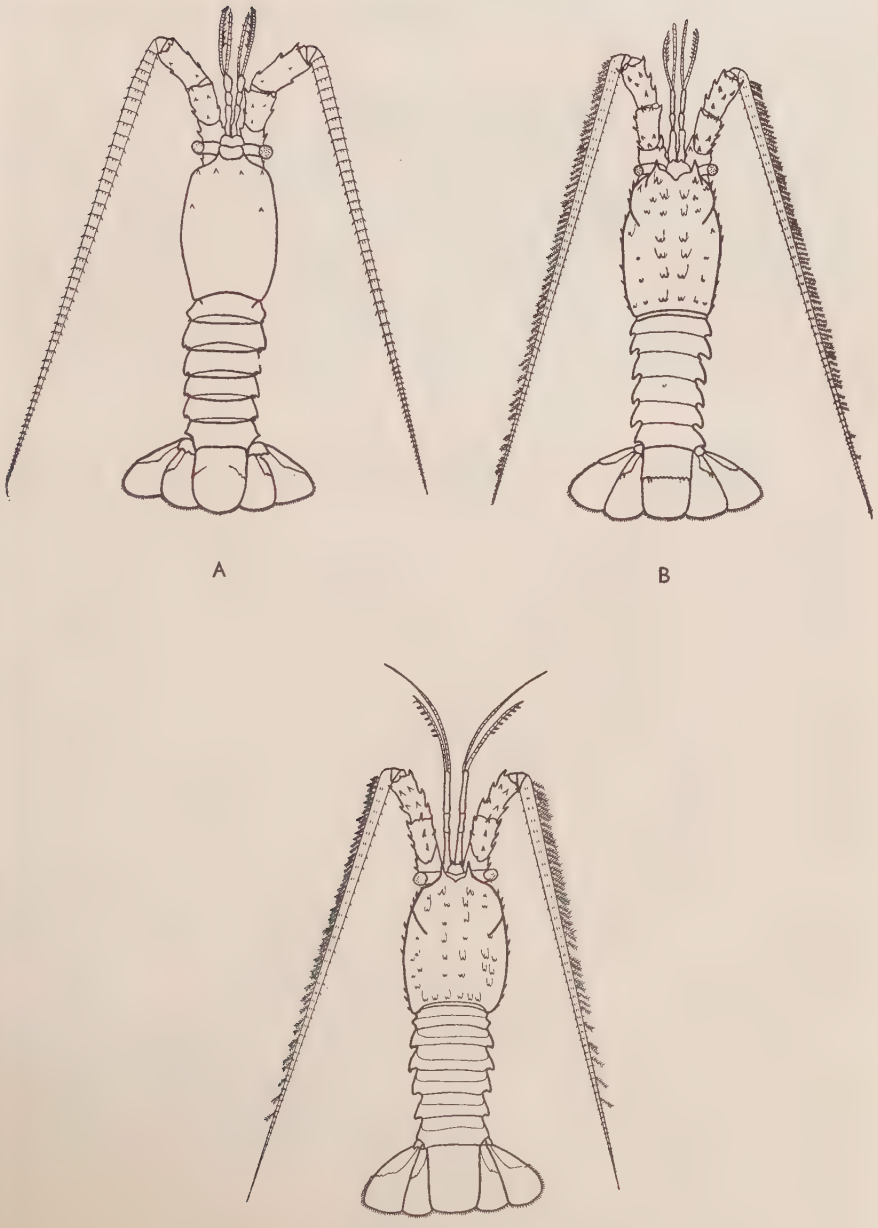

FIGURE 1. Post-larvae of *P. argus*. A, puerulus stage; B, stage 2; C, stage 3.

fourth pair, situated at about one third of the length of the carapace from the anterior end.

The rostrum is a small simple spine situated between the bases of the antennules. The antennules are relatively short, projecting only a little beyond the three basal segments of the antennae. The exopods and endopods are of equal length. The endopods bear a few sparse setae while the exopods are thickly setose. The peduncles of the antennae consist of three segments, do not bear all the principal spines of the adult and lack the smaller spines. The antennae are much longer than in the last larval stage. They are segmented and bear small forwardly directed spines at the lines of segmentation. The eyes have relatively longer stalks than do the eyes of the mature adult.

The mandible has the same general form as in the adult but bears ony a rudimentary palp. The incisor has no teeth. The first maxilla has the foliaceous form of the adult but bears no setae. The protopod is deeply cleft into two segments. The second protopod forms the major part of the maxilla while the first is a small segment at the base of the second. Opposite the first protopod, at the base of the second is the endopod which is about equal in size to the first protopod.

The second maxilla has a large well developed exopod fringed with setae. The endopod is very small and is triangular in shape. The endites are almost equal in size to the endopod and are not sharply differentiated from each other. The first maxillipede has a large exopod fringed with setae but the endopod is vestigial. The second maxillipede has a long unsegmented exopod which bears no setae. The endopod has a few setae on its pentultimate segment. The third maxillipede has a short, stout exopod which lies along the endopod. The last three segments of the endopod are provided with long spines encircling their distal ends. The epipod has the adult form except that it bears no setae and the gills are not completely formed.

The periopods bear vestigial exopods on the basipods. The segments of the periopods are rounded in section and the dactylopod bears a comb of fine setae. There are a few setae on the meropods. The gills and epipods have the adult form. All the pleopods are similar and bear endopods and exopods provided with a fringe of long setae. The endopod bears a small appendix at its base. The telson has the adult form.

Stage 2. FIGURES 1B, 2G-L, 3H and J.

The color is somewhat darker than in the final period of stage 1.

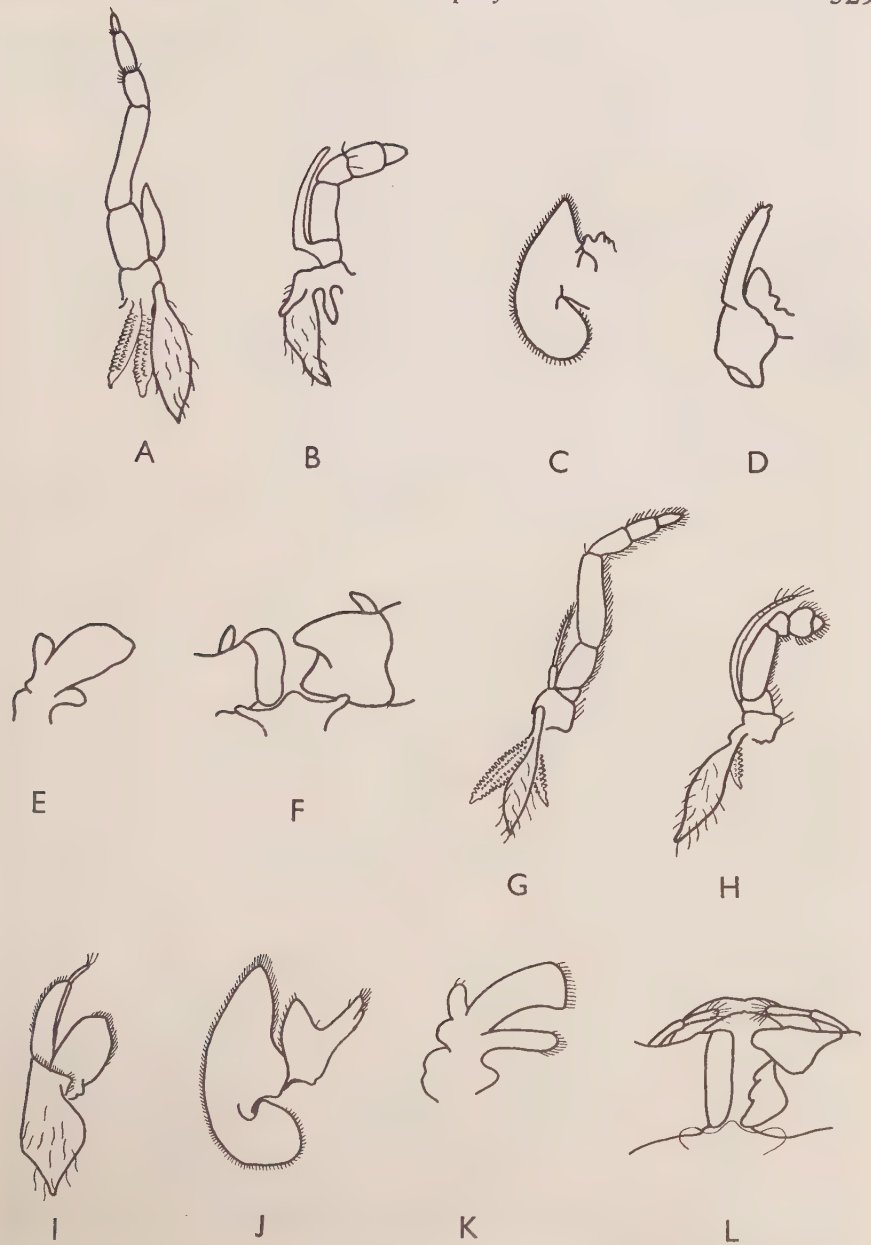

FIGURE 2. Mouthparts of post-larvae of *P. argus*. Puerulus stage, A-F; stage 2, G-L. A and G, 3rd. maxillipedes; B and H, 2nd maxillipedes; C and J, 2nd. maxillae; D and I, 1st. maxillipedes; E and K, 1st. maxillae; F and L, mandibles.

Just prior to moulting into stage 3, a purple stripe begins to develop between the two dorsal brown stripes. This purple stripe becomes more pronounced in the third stage. The color characteristic of the adult does not begin to develop until stage five or six.

The carapace is divided into two parts by a groove which runs from the base of the antennular peduncle back over the carapace, delimiting the anterior third of the carapace from the posterior two-thirds. There is a row of six pairs of spines on either side of the mid-dorsal line from just inside the bases of the ocular spines to the posterior end of the carapace. Just outside of these is another row of three pairs of smaller spines and finally towards the lateral edges of the carapace are two rows of irregularly placed spines. At the base off each spine on the carapace are one or two pairs of setae.

The antennular peduncles bear the principal spines of the adult. The endopods of the antennules are slightly longer than the exopods. The antennae are thickly fringed with irregularly placed, feathered setae.

The incisor of the mandible has developed three sharp teeth; the mandibular palp is composed of two segments and bears a number of setae at its tip. In the first maxilla the endopod has increased in length and has become widely separated from the rest of the maxilla. Both protopods bear a fringe of setae at their tips. The endopod of the second maxilla and its endites have become considerably enlarged and changed in this stage. The endites are widely separated from the endopod and have setae at their tips. The first endite is larger than the other two. The endopod bears setae on the edge nearest the exopod.

The first maxillipede bears a small triangular endopod fringed with setae. The epipod has numerous long setae. The tip of the exopod bears a short flagellum which in turn bears setae at its tip. The first and second protopods are fused into a single, large, shovel-shaped appendage. The exopod of the second maxillipede shows traces of segmentation, has a few setae at its tip and is almost equal in length to the endopod. The endopod is somewhat more flattened than in the first stage and bears numerous setae. The expod of the third maxillipede consists of a short basal segment and a larger flagellum fringed with setae. The total length of the exopod is about one third of the length of the endopod. The endopod is somewhat flattened and bears numerous setae.

The periopods are more flattened than in stage 1 and bear more numerous setae. The endopods of the pleopods have lost setae and

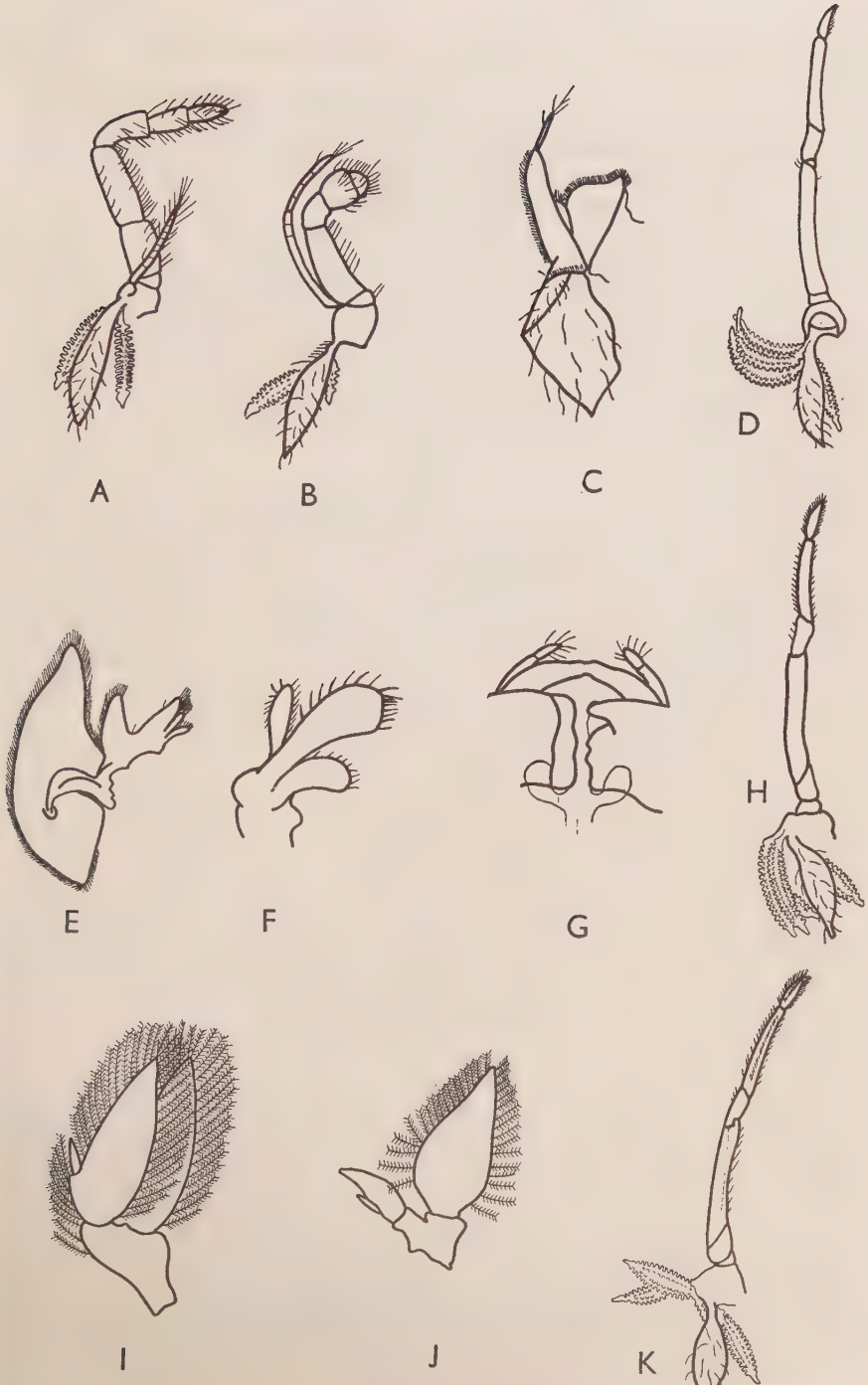

FIGURE 3. Mouthparts, first periopods and pleopods of *P. argus*. Stage 3, A, B, C, E, F, G, K. A, 3rd. maxillipede; B, 2nd. maxillipede; C, 1st. maxillipede; E, 2nd. maxilla; F, 1st. maxilla; G, mandibles; K, 1st. periopod; D, 1st. periopod of stage 1; H, 1st. periopod of stage 2; I, 1st. pleopod of stage 1; J, 1st. pleopod of stage 2.

have decreased in size to about one quarter the size of the pleopods of stage 1. The exopods are similar to those in stage 1 but the three last pleopods bear exopods which are slightly shorter and more rounded than the first (anterior) pleopods.

Stage 3. FIGURES 1C, 3A, B, C, E, F, G and K, 4A and G.

The rudiments of the many scale spines present on the carapace of the adult are visible. The ocular spines are longer and more slender and have more the appearance of the spines of the adult. The dorsal groove of the carapace has deepened. Transverse furrows are present on the abdominal tergites. The endopods of the antennules are longer relative to the exopods than in stage 2.

The constituent parts of the first maxilla bear numerous stout setae. The second protopodite is club-shaped and about half the length of the exopod. The endopod is of stouter proportions than in stage 2. The three endites of the second maxilla are distinct and the third is separated from the first two. All bear setae at their tips. The flagellum of the exopod of the first maxillipede is slightly less than one-third of the length of the endopod and bears a few long setae at its tip. The exopod of the second maxillipede is segmented in most specimens and is equal in length to the endopod. The endopod is quite markedly flattened. The setae on the endopod are more numerous than in stage 2. The basal segment of the exopod of the third maxillipede is much shorter than in stage 2. The flagellum is segmented and the endopod is flattened.

The periopods bear numerous setae and the segments are no longer round in section but angular with flattened sides as in the adult condition. The endopods of the pleopods are almost rudimentary. The small appendices which were present on the endopods in the first two stages are, however, still present as small stumps.

Later Stages. FIGURE *4.*

The later stages (up to stage 10) can be distinguished by the development of the pleopods. On the basis of the development of the endopods of the pleopods, the two sexes can be differentiated as early as stage 4 or 5.

In stage 3 the appendices of the endopods of the first and second pleopods are situated at about the middle of the endopod. In females of stage 4 the endopods have altered in shape so that the appendices lie nearer to the tips of the endopods. In the second pleopod (and subsequent ones) the end of the appendix lies even with the end of

the endopod. In the first pleopod the appendix is slightly lower on the endopod. There are one or two setae present near the tips of the endopods in most specimens.

In males of stage 4 the appendices are unaltered in their position on the endopod. They have shrunk considerably to small buds. In stage 5 males the appendices of the endopods are vestigial and the

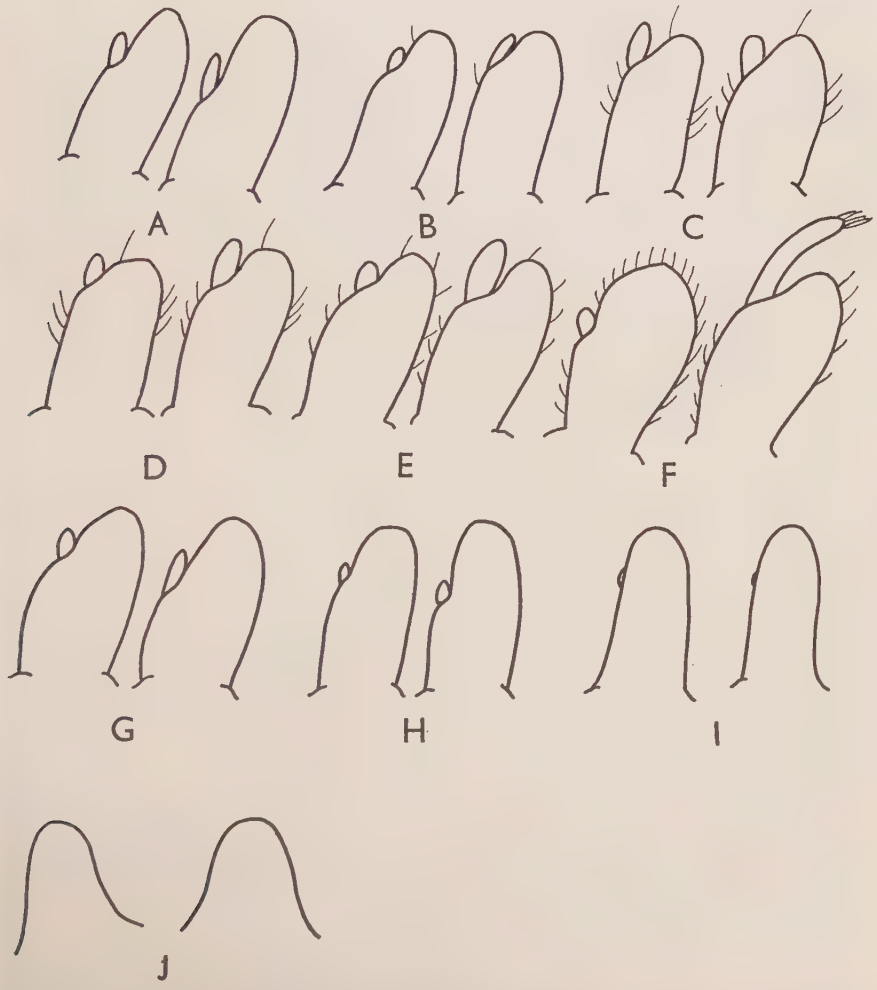

FIGURE 4. Endopods of first and second pleopods of *P. argus*. A-F, females; G-I, males. A, stage 3; B, stage 4; C, stage 5; D, stage 6; E, stage 8; F, stage 10; G, stage 3; H, stage 4; I, stage 5; J, stage 6.

endopods themselves are thinner and less robust than are the endopods of the previous stage. In stage 6 there are no traces of the appendices and the endopods are merely stumps and have become heavily calcified.

In females of stage 5 the endopods of the first pleopods are somewhat slenderer than the rest. All endopods bear three setae at their tips and three on either side.

Beyond stage 5 only a few females were obtained. Thus from a limited number of specimens, the following line of development was evidenced. There is little change in stage 6 from the condition of stage 5. The appendices are slightly larger, particularly on the endopods of the second pleopods and the endopods themselves are somewhat enlarged. By stage 8 the appendix of the endopod of the second pleopods has increased to almost double the size of those of stage 6. In stage 10 the endopod of the first pair of pleopods has enlarged considerably and has assumed a shape similar to that of the exopod. The endopod is fringed with setae in this stage. There is a long straplike appendix on the endopod of the second pleopod. The endopod is fringed with setae and the appendix bears a number of setae on its tip.

Growth

Growth studies based on measurements from animals reared away from their normal environment are inevitably subject to a certain amount of criticism. While it is doubtless impossible to duplicate exactly the conditions under which normal growth takes place, it is felt that data obtained from the reared larvae give at least some indication of the animals real growth rate. The fact that young lobsters passed through as many as six successive moults indicates that their environment was suitable although not necessarily ideal. In addition, the paucity of existing reliable data on the growth rate of *Panulirus argus* makes any information on growth important.

It was found that the most reliable length measurements were those of the carapace. Measurements were made with dividers and the distance marked off on a steel millimeter scale. The measurements were made from the posterior edge of the carapace to the apex of the crotch that is between the ocular spines.

Fig. 5 shows the relationship between the length of the carapace and age (by stages). The growth curve of stages 1 to 5 inclusive (solid line) is derived from the averages of the carapace lengths of a considerable number of specimens of each stage. Because there were

a limited number of specimens larger than stage 5, the lengths and stages of the individual specimens have been plotted (broken lines).

Table I includes the average carapace lengths of stages 1 to 5 with the number of specimens and the carapace lengths of all idividuals larger than stage 5. The identification of stages one to five was made from a total of 94 specimens. It was possible to identify the subsequent stages because a number of the lobsters passed through several successive moults from stage 4 or 5. For example, specimen No. 2 (see Figure 5) was captured as a known stage 4 and underwent six moults to stage 10 before it died. Similarly, with the other specimens that passed through several successive moults, it was possible to establish the identity of the first captured stage.

Figure 5 indicates that a metamorphosed individual of 6 mm. carapace length attains a carapace length of 18 mm. after the tenth moult. Since the average period between moults was found to be 33 days,

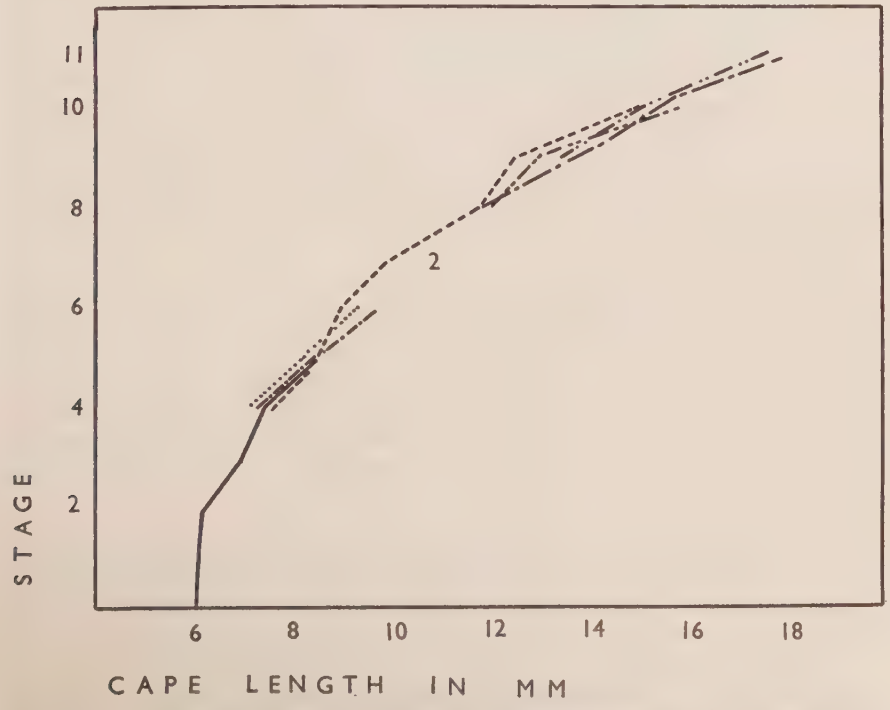

FIGURE 5. Relation of age (by stages) to carapace length of *P. argus*. Solid line, average length of stages 1-5 inclusive; broken lines, successive moults of individual specimens.

TABLE I

CARAPACE LENGTHS (MM.) OF POST LARVAL STAGES

Stage	*Length*	*No. of Specimens*	*Stage*	*Length*
1	0.61	25	9	1.39
2	0.62	32		1.25
3	0.70	19		1.38
4	0.75	10		1.40
5	0.85	8		1.30
6	0.95		10	1.49
	0.90			1.50
	0.95			1.55
	0.90			1.61
7	1.00		11	1.73
	1.02			1.80
8	1.18			
	1.18			
	1.20			

a young lobster would pass its tenth moult in a little less than one year. This represents an increase in carapace length of 12 mm. (½ inch, approximately) in the first year.

In both 1950 and 1951 the bulk of the pueruli were captured in January. A small number were taken in February and until the end of March. The period of greatest settlement coincides with the period during which the last larval stages were taken in the Gulf Stream off Miami (Lewis, 1951).

A detailed analysis of the factors influencing growth was not possible because of the limited number of specimens available beyond stage 3. Temperature was found to influence the growth increment but the magnitude of the effect is not known. The period between moults varied from 14 to 57 days with an average intermoult period of 33 days. There was no significant difference in intermoult periods between the stages nor any evidence of a difference in length between the sexes.

Although measurements of abdomen lengths were found to be unreliable, it is interesting to calculate the total increase in length of the young adults during the first year. The puerulus stage of cape length 6 mm was found to have an abdomen length of approximately 11 mm. A young adult which had moulted 10 times (stage 11) had a cape length of 18 mm. and an abdomen length of 32 mm. Thus the overall length of a puerulus stage was 17 mm. and that of a stage 11 young adult was 50 mm. The increase in the first year is thus 33

mm. (1.3 inches). This estimate is close to that of Smith (1951) for at least the first year of growth.

REFERENCES

Bouvier, E. L.

1914. Recherches sur le développement post-embryonnaire de la langouste commune, *Palinurus vulgaris*. J. Mar. Biol. Assoc. U.K., *10*(2); 179 - 193.

Calman, W. T.

1909. The genus *Puerulus* Ortmann and the post larval development of spiny lobsters (Palinuridae). Ann. Mag. Nat. Hist., ser. 8, *3:* 441-446.

Gurney, R.

1942. Larvae of Decapod Crustacea. 306 pp. Ray Society Monographs, 1942, London.

Leach, W. E.

1817. Tuckey's narrative of an expedition to explore the river Zaire. London, Appendix 4, (Crustacea) : 413 - 418.

Lewis, J. B.

1951. The phyllosoma larvae of the spiny lobster *Panulirus argus*. Bull. Mar. Sci. Gulf & Caribbean, *1* (2) : 89 - 103.

Smith, F. G. W.

1948. The spiny lobster of the Caribbean and Florida. Caribbean Research Council, Fisheries Ser. (3) : 1 - 58.

Smith, F. G. W.

1951. Caribbean spiny lobster investigations. Proc. Gulf and Caribbean Fish. Inst., Nov., 1950 : 128 - 134.

MARINE MONOCOTYLEDONOUS PLANTS OF BERMUDA[1]

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ABSTRACT

Early records of *Zostera marina* remain unconfirmed, but records of *Diplanthera Wrightii, Cymodocea manatorum,* and *Thalassia testudinum* are confirmed and supplemented by observations on stations and habits of growth. An unattached specimen of *Halophila Baillonis,* previously unknown from Bermuda, and specimens of this species from other Caribbean areas are placed on record.

The role of *Thalassia* colonies that promote sedimentation on the floors of bays by accumulating calcareous debris is described.

During a study of the ecology of the algae of Bermuda in 1949, 1950, and 1951, considerable attention was given to the sea-grasses which are monocotyledonous plants that spend the greater part of their existence completely submerged. The absence of any single comprehensive treatment of this group as it occurs in Bermuda necessitated a search of the literature, from which it became apparent that the situation at the present has changed somewhat since the reports of earlier authors. In the following paper an attempt is made to bring the scattered references up to date on the basis of personal observations and to comment on certain aspects which are usually omitted from purely taxonomic works.

The writer wishes to express his gratitude for suggestions and guidance furnished by Professor William Randolph Taylor of the University of Michigan, and for the unstinting cooperation of the former director of the Bermuda Biological Station, Professor Dugald E. S. Brown, and the present director, Doctor Louis W. Hutchins.

Diplanthera Wrightii (Ascherson) Ascherson. (*Halodule Wrightii* Ascherson). Although this species is fairly common at present in Bermuda, it has been either absent or overlooked until recently. Britton's definitive flora (1918), which includes the records of many early botanists, did not report *Diplanthera.* Prat (1935) also omitted mention of *Diplanthera* from his descriptions of the terrestrial and marine vegetation of Bermuda. In 1936 Rendle published his notes on changes in the vegetation after Britton's time, but he also said nothing about this plant, although he discussed the other sea-grasses. Rendle collected some algae in Hungry Bay, where *Diplanthera* was

1 Contribution No. 965 from the Department of Botany, University of Michigan, and No. 167 from the Bermuda Biological Station.

conspicuous in 1951, and his failure to record the species may mean that *D. Wrightii* is a comparative newcomer to the region.

The first reference to *D. Wrightii* in Bermuda seems to have been that of Ostenfeld (1927) but he did not cite specimens. Feldmann's (1938) inclusion of Bermuda in the range for this species was based on Ostenfeld's report and not on personal knowledge (private communication). In a paper of limited distribution, Moore (n.d., 1947?) mentioned *D. Wrightii* (as *Halodule Wrightii*) with some comments about the ecology of Richardsons Cove and other mangrove bays. His tentative determination was undoubtedly correct, for the species was prominent, though not abundant, in Richardsons Cove in 1949-50.

During 1949-51 *D. Wrightii* was seen at several bays on St. Georges I., St. Davids I., and Hamilton I., and herbarium specimens were taken from a stand of particularly well-developed plants at Hungry Bay, on the south side of Hamilton I. It is a plant of shallow protected bays, growing on sand or mud, always on a soft bottom. In this respect it differs from *Thalassia* and *Cymodocea,* which occur on firm sand as well as on shifting sand or mud. In some areas, for example Richardsons Cove and Mullet Bay, St. Georges I., dwarfed and blackened growths of this species occurred at the shore where they were partially exposed at each low tide. The moribund appearance of these stunted plants suggests they were mere stragglers which were able to get started but unable to flourish in very shallow water. Regrettably, it was never possible to connect them with any stands of healthy, typical plants and it may be that there exists here a subspecies or variety, which occupies its own niche. None of the dwarfed material obtained was in condition suitable for herbarium preparations.

Because of the absence of previous authenticated reports, it seemed desirable to check carefully the identity of the typical plants. All the material was sterile. In general appearance it agreed with specimens of *Diplanthera Wrightii* at the Herbarium of the University of Michigan. The flattened leaves, which were about 2 mm. wide, are conspicuously different from the terete leaves of *Cymodocea* and are much narrower than the strap-like leaves of *Thalassia* and *Zostera.* When a portion of the leaf was decolorized with javelle water and compared with similarly treated fragments of herbarium specimens of *Zostera marina, Cymodocea manatorum, Thalassia testudinum,* and *Diplanthera Wrightii,* it was found to coincide with only the last of these in arrangement, shape, and size of epidermal cells, whereas the

other species were very different from *Diplanthera* and from one another.

There is, however, another species, *D. uninervis,* which has been reported to be superficially indistinguishable from *D. Wrightii* but no herbarium material was available by which comparisons of the epidermal cells could be made so as to differentiate the two. Fortunately, however, other vegetative criteria that involve the tip of the leaf and the cross section anatomy near the base of the leaf have been described by Sauvageau (1890) and Feldmann (1938) and can be used for identification purposes as follows. They observed that in *D. Wrightii* the cells capping the median nerve were lacking and that the outline of the top of the leaf accordingly bore a prominence at each margin only, whereas in *D. uninervis* the outline of the leaf tip was characterized by a prominence at the center as well as at each margin. On this basis, since the Bermuda material lacked the cap on the median nerve, the plant found was considered *D. Wrightii.*

A word of caution is in order at this point because Sauvageau warned that the central apical cap may be present on young leaves of *D. Wrightii,* and the species was figured by Muenscher (1944, fig. 22, as *Halodule Wrightii*) with the central apical cap but with no mention that this was not the typical case. Moreover, the author has seen a Florida specimen of *Diplanthera Wrightii* with both leaf conditions on the same plant. Thus, presumably a young specimen of *D. Wrightii* with three nubbins on each leaf can be mistaken for *D. uninervis* if Sauvageau's warning were ignored, but fortunately the question did not arise in the present study.

The other character employed by Sauvageau and by Feldmann was the presence of lacunae around the median nerve of *D. Wrightii* in contrast to the small intercellular spaces of the corresponding tissue in *D. uninervis* (Sauvageau 1890, figs. 2, 5, as *Halodule*). In this character also the Bermuda plants agree with *D. Wrightii.*

According to Ostenfeld (1927, map 34), *Diplanthera Wrightii* is essentially a Caribbean species. Its range outside of Bermuda includes Florida, the Bahamas, the Greater and Lesser Antilles, and Panama, where it was found on the Pacific as well as on the Atlantic side.

The Bermuda collection (Hamilton I., Hungry Bay, Bernatowicz *no. 51-870,* 6 Feb. 1951) has been deposited in the Herbarium of the University of Michigan.

Cymodocea manatorum Ascherson. (*Syringodium filiforme* Kütz.) The manatee grass is a characteristic member of the flora of quiet bays

throughout Bermuda. Whereas the other Bermuda sea-grasses have flattened leaves, the leaves of *Cymodocea* are essentially cylindrical, about 2 mm. in diameter and 3 dm. or more long. In its rhizomatous habit and general dimensions it resembles *Diplanthera,* but colonies of the two may be distinguished by the more erect habit of *Cymodocea* in contrast to the flexuous or drooping aspect of *Diplanthera.* When inspected, the plants are readily distinguishable on the basis of terete *versus* flattened leaves.

Cymodocea forms extensive beds on bottoms of sand or gritty mud at Richardsons Cove, Mullet Bay, and Coot Pond on St. Georges I., at Wells Bay on Coopers I., and at many other bays in Castle Harbor, Hamilton I., Harringson Sound, *etc.* It is most often seen just below the low tide level, but grows taller and more luxuriantly in depths of 2-4 meters (or more?). The detached upper parts are a frequent feature of the debris cast ashore after storms.

Britton reported flowers in spring or summer, but they were apparently infrequent. Although constantly watched for, flowers were found by the author only once, in June, on drifting fragments.

Zostera marina Linnaeus. Britton (1918), who listed Greenland to Florida as the distribution of this *Zostera,* believed it to be native to Bermuda, although he did not find it growing there. Rather, his report was based on specimens cast up on the north shore after a storm and he presumed the source to be the Bermuda Bank. Ostenfeld (1927) did not include Bermuda in the range for this species, considering that it extended northward from somewhat south of New York. He was aware of reports of a more southerly range but noted that they were not supported by herbarium specimens. Prat (1935) mentioned *Zostera* as one of the marine phanerogams of Bermuda, but the author has not been able to determine whether the observation was supported by herbarium specimens.

The author has not found the species, either in place or cast ashore, although he has visited the reefs and shoals which stretch for several miles off Bermuda's north shores and has collected algae in many Bermudian bays which resemble the *Zostera* habitats of the New England coast.

The absence of *Zostera* from Bermuda at the present time can not be considered a refutation of Britton's and Prat's reports because the well-known disappearance of eel grass from the American and European coasts about 1931-34 may have also occurred in Bermuda. If this is the case, *Zostera* may become re-established in Bermuda; but,

since this would probably depend on waifs carried from American shores, it would lag far behind the slow return of *Zostera* on the Atlantic coast.

On the other hand, any assumption that Britton's specimens must have been torn loose from the Bermuda Banks because of the remoteness of Bermuda from any other land mass is not completely justified. According to Guppy (1917), Bermuda receives drift vegetation from all points of the compass, and certainly *Ascophyllum nodosum,* an alga whose range in America agrees fairly well with that of *Zostera,* has been cast ashore at Bermuda. To be sure, it is not known whether *Zostera* can float as far as *Ascophyllum,* but at least the winds and currents are not an insuperable barrier between Bermuda and the continent.

In the event that *Zostera* is found at Bermuda in the future it should be interesting to observe how long its recolonization might lag behind its re-establishment in America, and at what rate the colonies might spread through the islands.

Thalassia testudinum Konig. The plant known as turtle grass is the most abundant and conspicuous of the Bermuda sea-grasses. The author has not found flowering specimens nor any record of its time of flowering at Bermuda. However, it is readily distinguished by the stout jointed rhizomes and broad leaves which are 0.5 to 1 cm. wide with heavy sheaths at the bases. It is rarely free of epiphytes, among which are *Fosliella, Ceramium, Aegira,* and other algae.

Thalassia grows on mud or sand in quiet bays everywhere and is also subjected to some wave action, as at St. Catherine's Point on St. Georges I., and in the passage between Charles I. and Castle I. In muddy areas it forms continuous meadows, but on firmer bottoms it is found in patches which, even though they may be more than 100 square meters in area, are conspicuously elevated above the surrounding bottom. These elevations are caused by an accumulation of pebbles, shells, and fragments of calcareous algae which are bound together by the strong rhizomes of *Thalassia.* Along the seaward edge a patch does not taper down to the original bottom but ends abruptly, and here the thickness of the mat of calcareous debris is about 1.5 dm. The expansion of the mat probably takes place in two ways: (1) debris washed in by waves lodges against the seaward fence of the mat and is caught among the exposed roots of the plant, whereupon the plants are able to advance out from shore; and (2) at the same time, calcareous algae, especially *Halimeda* but also *Penicillus* and *Udotea,*

grow in abundance among the *Thalassia* plants furnishing their own skeletons that add to the thickness of the mat. Where such a mat extends out from shore, as at Whalebone Bay on St. Georges I., and Wells Bay, Coopers I., it seems probable that portions of the bay are being reclaimed from the sea in a manner similar to that of the mangroves which tend to fill in bays where they grow. If this be the case, a very different end-product from the mangrove deposits would result. Thus, under mangroves a peaty substratum is formed which grades off in a short distance to mud and soil, whereas land exposed as a result of *Thalassia* mats would be calcareous, resembling an unconsolidated phase of the Aeolian limestone of which Bermuda is composed.

Halophila Baillonis Ascherson. This delicate species is especially different from the other marine phanerogams described here because its thin small leaves which are scarcely 2 cm. long, are not graminoid but are oval and petiolate. It has never been listed from Bermuda and the present report is regrettably not conclusive, since it concerns a detached fragment. On December 14, 1950, following several days of rough seas, a small specimen of this plant was found entangled in a fishtrap pulled up from 5-6 meters depth at Castle Roads, on the south side of Bermuda. The fragment is only about 2 cm. long, has two pairs of leaves, and is sterile, but the opposed leaves, the presence of unicellular hairs on their surfaces, and the small dimensions of the plant parts leave no doubt as to its identity.

In America, according to Taylor's (1928) first hand account of the marine phanerogams of Dry Tortugas, *Halophila Baillonis* seems to be a deep water plant, for he recorded it from depths of 5.5 to 29.3 meters, generally from 14 to 18 meters. Feldmann (1937) emphasized that in Guadeloupe the species grows in the most calm places, usually on mud at depths of 6 to 15 meters but sometimes near low tide level. A search of several protected bays in the area where the plant was found in Bermuda was without success, and no more fragments were found among the vegetation cast ashore.

This species is known from south Florida, the Florida Keys, Jamaica, Virgin Is., Guadeloupe, Martinique, and Curaçao. The nearest stations of collections are, then, more than 750 miles away. Since Guppy (1917) stated that plant parts can reach Bermuda from the Florida-Antillean region, the Bermuda specimen may be a mere waif, but the very possibility that a plant of such delicacy could travel so great a distance would appear to be noteworthy. An alternative hypothesis, and one which seems more reasonable, is that the plant is native

to Bermuda, growing either in the deep waters outside the south reefs where no botanical exploration has been attempted, or on inshore areas where its small size and propensity for deep waters have precluded its detection.

Because of the paucity of citations of actual specimens in reports concerning *Halophila Baillonis,* it seems advisable to place on record not only the Bermuda specimen but also the following other previously unreported collections deposited in the Herbarium of the University of Michigan (M), and in the personal herbarium of Wm. Randolph Taylor (T) at Ann Arbor: BRITISH WEST INDIES, Tobago I., on mud at 16-32 meters, Taylor *no. 39-504,* 19 April 1939, (T); Barbados, Bridgetown, dredged 12 meters, Schmitt and Lunz, 20 April 1937, (M); VIRGIN Is., St. Thomas, Charlotte Amalie, dredged 2.4-6 meters on a sandy bottom, Schmitt and Lunz, 5 April 1937, (M,T); FLORIDA, Dry Tortugas, dredged 30 meters, Bowman, July 1915, (M); *ibid.,* Southwest Channel, dredged 14-18 meters, Taylor, 11 June 1925, (T); *ibid.,* near Southwest Key, dredged 1.8-5.7 meters, Taylor, 19 June 1925, (T); *ibid.,* White Shoal, dredged 10.8-14 meters, Taylor, 17 and 19 July, 1924, (T); BERMUDA, Castle Roads, on a fishtrap, 5-6 meters, Bernatowicz *no. 50-447,* 14 Dec. 1950, (M).

REFERENCES

Britton, N. L.
1918. Flora of Bermuda. xi+585 pp., illus. Scribner's, New York.

Feldman, J.
1937. Les monocotylédones marines de la Guadeloupe. Bull. Soc. Bot. France, *83:* 604—613, 1 fig.
1938. Sur la répartition du *Diplanthera Wrightii Aschers.* sur la côte occidentale d'Afrique. Bull. Soc. Hist. Nat. Afr. N., *29:* 107—112, 1 fig.

Guppy, H. B.
1917. Plants, seeds, and currents in the West Indies and Azores. xi+531 pp. Williams and Norgate, London.

Moore, H. B.
n. d. *ca.* 1947. Ecological guide to Bermuda inshore waters. 48 pp., 18 figs. Bermuda Biol. Sta. for Research, Inc., Bermuda.

Muenscher, W. C.
1944. Aquatic plants of the United States. x+374 pp., 154 figs. and 400 maps. Comstock, Ithaca, N. Y.

Ostenfeld, C. H.
1927. Meeresgräser II. Potamogetonaceae. Pflanzenareale, *1* (4): 46—50, maps 34—39.

Prat, H.

1935. Notes botaniques sur l'Archipel des Bermudes. Bull. Soc. Bot. France, *82:* 162—168, 2 figs.

Rendle, A. B.

1936. Notes on the flora of the Bermudas. J. Bot., Lond., *74:* 42—50, 65—71, 101—112, 1 map.

Sauvageau, C.

1890. Sur la structure de la feuille des genres *Halodule* et *Phyllospadix*. J. Bot., Paris, 4: 321—332, figs. 1—7.

Taylor, W. R.

1928. The marine algae of Florida with special reference to the Dry Tortugas. Carnegie Inst. Wash. Publ. (379): 1—219, 37 pl.

SCHISTOSOME CERCARIAE AS THE PROBABLE CAUSE OF SEABATHER'S ERUPTION[1]

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ABSTRACT

At the beginning of this investigation, there was no proof as to the identity of the causative agent of sea-bather's eruption, an acute form of dermatitis occurring on some people bathing in certain marine areas of the southwestern North Atlantic Ocean. During the course of this study, it was demonstrated by laboratory experiments that a species of marine schistosome cercaria found in the Florida area is capable of producing a dermatitis. Lesions produced experimentally appear to be identical with those of naturally occurring cases of seabather's eruption.

INTRODUCTION

During recent years frequent reports have been received of an acute form of dermatitis resulting from bathing in the ocean waters of certain areas of the lower Florida coasts and surrounding areas. At certain times, it has rendered many beaches of the lower Florida east coast unsuitable for bathing. It is therefore important economically and scientifically as well as from the standpoint of protecting public health and the need for a comprehensive investigation has long been recognized.

Seabather's eruption has been referred to in the past by many names, the most common of which is "sea lice." It has been reported at least as early as 1923 from the Miami-Miami Beach area. The first mention of it in the literature, however, appears to be by Thomas in 1939. He reported it as an eruption which occurred characteristically beneath the bathing suit. Sams (1949) gave a very thorough account of its clinical nature. Also, he stated that seabather's eruption should not be confused with "swimmer's itch" (schistosome dermatitis), a condition which, at the time of his writing, was known to occur only in fresh water and which frequently occurred on the exposed areas of the hands and feet. Penner (1950) has since shown that swimmer's itch does occur in marine waters.

Typically, seabather's eruption occurs predominantly on those parts of the body covered by the bathing suit and is characterized by erythematous wheals, an abnormal redness of the skin due to capillary congestion. In some cases, there is a slight pricking while the bather is still in the water, but in most cases, discomfort is not noticed until

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leaving the water. The principal difference between seabather's eruption and published accounts of swimmer's itch is that the former condition occurs predominantly on those parts of the body covered by the bathing suit while the latter condition is most frequently confined to the exposed parts of the body. Swimmer's itch has been attributed to schistosome cercariae which penetrate the skin causing the dermatitis (Cort, 1928; and others). Penner (1950) reported a similar dermatitis-producing schistosome cercaria from the marine snail *Littorina planaxis* Philippi but failed to give a detailed account of the clinical nature of the dermatitis other than stating that the intensity and duration were similar to the fresh water schistosome dermatitis.

Carroll, Hill, and McElrath (1947) discussed what is apparently another type of bather's itch which occurs in certain Florida freshwater lakes of the Gainesville area. This itch is similar to seabather's eruption in that it occurs predominantly underneath the bathing suit, but these writers believed it to be an allergic dermatitis rather than a parasitic disturbance.

It was at the suggestion of Dr. T. E. Cato, Director of the Dade County Health Department, that the present investigation was carried out with the financial assistance of the Dade County Commission and Miami Beach City Council. Special thanks are due Dr. F. G. Walton Smith, Dr. Hilary B. Moore, Gilbert Voss, and Donald Moore, all of the Marine Laboratory, University of Miami, for their valuable assistance in various phases of this work. Among many others to whom I am especially indebted for their kind cooperation are Captain Earl Pindar and staff of the Miami Beach Lifeguard Station, Dr. W. Henry Leigh, Dr. Wiley Sams, Dr. Philipp Rezek, and Dr. T. E. Cato.

Methods

The present investigation in southern Florida began on January 1, 1950 and continued through August, 1951. The primary objective of the study was to determine the causative agent, or agents, of seabather's eruption so that a practical means of control could be determined.

Efforts were made to determine the geographical distribution and seasonal occurrence of the dermatitis, along with case history studies, investigation of naturally occurring cases, examination of plankton hauls and water samples, and experiments with possible causative agents.

Geographical Distribution

It was previously believed that seabather's eruption was confined to Florida waters. More recent correspondence showed that although most common along the lower Florida east coast, it has a somewhat wider range. Truitt (personal communication) reported a dermatitis very similar to, if not the same as, seabather's eruption occurring occasionally in the lower Chesapeake Bay, especially around Cape Henry and at Ocean City, Maryland. Particularly during June or early July of certain years, a number of cases were reported.

Reports from lifeguards and marine investigators, as well as from physicians, indicated severe outbreaks of "sea lice" from West Palm Beach southward, including the Florida Keys, the Bahamas, Cuba, Jamaica, Grand Cayman, St. Catherine, and St. Thomas. Some cases, but relatively few, have been recorded from Bermuda, Jacksonville on the east coast of Florida, and from Cortez Bay and St. Petersburg on the Gulf coast. Although considerable correspondence was carried out with investigators in the various Gulf states, no record of a similar dermatitis was received from any Gulf state other than Florida, and no reports were received from the Gulf side of this state north of St. Petersburg. Likewise, other than the dermatitis reported by Truitt, no reports were received from any of the Atlantic coast states north of Jacksonville, Florida. Stunkard (1951) reported schistosome dermatitis from the marine waters of Rhode Island, but this appears to be the same as that described by Cort (1928 and 1950) since it occurs predominantly on the exposed areas of the skin.

Seasonal Incidence

Seabather's eruption is without question a seasonal phenomenon in certain south Florida regions. Over a 15 year period, the major outbreaks at Miami Beach, Florida, have occurred during the months of May and July, with the largest number of cases being reported during the month of July, 1944, when several thousand cases were reported over a period of 15 days. Table I shows 22 separate outbreaks of seabather's eruption occurring at Miami Beach, Florida, from 1936 to 1950. Of these 22 separate outbreaks, 17 were of one day duration while the remaining five were reported over a period of from three to 15 days. It should be pointed out that all 22 attacks occurred during the months of March to August. This clearly demonstrates that it was a seasonal phenomenon in the Miami Beach area during these years. This, in general, agrees with reports from other south Florida com-

TABLE I

MONTHS DURING WHICH SEABATHER'S ERUPTION HAS OCCURRED AT MIAMI BEACH, FLORIDA FROM 1936 TO 1950*

Year / *Month*	1936	'37	'38	'39	'40	41	'42	'43	'44	'45	'46	'47	'48	'49	'50
January	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
February	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
March	—	+	—	+	—	—	—	—	—	—	—	—	—	—	—
April	—	—	+	—	—	—	—	—	—	+	—	+	—	—	+
May	+	+	+	—	—	—	—	+	—	+	—	—	—	+	+
June	+	—	—	—	—	—	—	+	—	—	—	—	+	—	—
July	+	—	—	—	—	—	—	—	+	—	—	—	—	—	—
August	—	+	—	—	—	+	—	—	—	—	—	—	—	—	—
September	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
October	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
November	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
December	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

* Information for this Table was obtained from records of the Miami Herald, the Miami Beach Lifeguard Station, and various local physicians.

— Months during which Seabather's Eruption did not occur.

\+ Months during which Seabather's Eruption did occur.

munities. Further south, in the West Indies, there have been some cases reported during all seasons of the year, but in most cases, they were confined to the months of April, May, June, and July.

Case Histories

Individual case histories of people who have suffered from seabather's eruption were helpful in determining the geographical distribution and seasonal occurrence of the dermatitis as well as in giving additional information as to possible causative agents. Furthermore, the studies indicated that the dermatitis occurred on exposed areas of the skin as well as underneath the bathing suit, but that the lesions on the exposed parts seldom appeared to be as severe as those occurring underneath the bathing suit. These case histories are much too lengthy to include here, but they are on file in the Marine Laboratory, University of Miami, Coral Gables, Florida.

Investigation of Naturally Occurring Cases

During the course of this investigation, a number of bathers who developed a dermatitis while bathing in ocean waters were examined. Many of these bathers were suffering from some type of coelenterate sting (hydroid, Portuguese Man-of-War, or jellyfish) rather than from seabather's eruption. In general, the cases of seabather's eruption viewed confirm the observations of Sams (1949) that the eruptions occur predominantly underneath the bathing suit. However, in many cases, a less severe dermatitis, as compared with the one occurring beneath the bathing suit, was observed on the exposed parts of the skin of the arms and legs. This dermatitis is similar to the one occurring underneath the bathing suit in the following ways: (1) the lesions are widespread and there is no clear-cut pattern of distribution; (2) the bather may experience a slight pricking sensation while in the water, but, more usually, shortly after leaving it; (3) this initial pricking is generally followed by a period of from one to several hours during which time no discomfort is experienced; (4) at the end of this latent period, a more severe itching occurs and small eruptive pustules appear; and, (5) the itching may last from three to 11 or 12 days after which the lesions disappear. In view of the above facts, it seems likely that the etiology of the dermatitis occurring on the exposed parts of the skin and the one occurring underneath the bathing suit (seabather's eruption) is the same, the one being a variation of the other.

Sams (1949) reported that histological examinations revealed no foreign bodies or parasites in material excised from patients. Since none of his material was obtained at an earlier time than 24 hours following exposure, attempts were made to obtain a subject willing to submit to a biopsy at a much shorter interval following exposure. Very few cases were reported during this study, however, and only one such subject was obtained. Since this case was reported on the morning following exposure to the dermatitis, between 23 and 24 hours had elapsed before the biopsy was made. The general picture of the sectioned lesion was the same as reported by Sams (1949) with no foreign bodies or parasites visible. It should be noted here that Brackett (1940), in his work on schistosome dermatitis, was unable to demonstrate parasites in the epithelial layer 29 hours following exposure, but that Vogel (1930), working with *Cercaria ocellata,* was able to demonstrate the parasites 24 hours after experimental infection of human subjects.

Examination of Plankton Hauls and Water Samples

During the first 10 months of 1950, weekly plankton hauls and water samples were taken from the inshore waters of a marine station set up at Miami Beach, Florida. In order to determine possible causative agents the plankton hauls were made by wading into the surf and towing a No. 20 plankton net at the surface for approximately 10 minutes. The water samples were taken in a one gallon jar both at the surface and at various depths. Both the hauls and the samples were examined underneath the dissecting microscope and later preserved in a 4% solution of formaldehyde neutralized with borax. The reason for preserving the hauls and samples was that cases of seabather's eruption were frequently not reported until the day after the swimmer experienced the dermatitis. It was hoped that if any cases were reported on the days when hauls and samples were taken, they would reveal some evidence as to the nature of the causative agent.

In one instance, a woman experienced seabather's eruption at the time and at the place where the writer was taking a plankton haul. The eruptions were confined to those areas covered by the bathing suit; however, she complained of itching on exposed areas as well as the areas of the skin underneath her bathing suit. At the time, approximately 150 bathers were in the same area where the woman experienced the dermatitis yet not one of these bathers was bothered.

Concentrated samples from plankton hauls from this same area were placed on the skin of various volunteers without a rash developing. Microscopic examination of plankton hauls and water samples revealed no organisms which could conceivably have caused the dermatitis.

Experiments with Possible Causative Agents

Among agencies which could be reasonably suspected on *a priori* grounds the following were considered: (1) individual sensitivity (allergic dermatitis); (2) various forms of plant life having spines and, or, containing poison; (3) protozoans with spines or trichocysts; (4) sponge spicules; (5) some type of coelenterate; (6) marine schistosome cercariae; (7) planktonic polychaetes bearing spines; (8) planktonic crustaceans, such as the zoea or megalopa stage of the crab; and (9) miscellaneous planktonic organisms with spines.

With the above agencies in mind, many marine organisms were tried on human subjects, but relatively few were found to cause a dermatitis of any type. Among those that did were the sponges, *Tedania ignis* Duchassaing and Michelotti and *Spheciospongia vesparia* (Lamarck); the hydroid, *Pennaria tiarella* (Ayres); the Portuguese Man-of-War, *Physalia pelagica* Lamarck; the jellyfish, *Aurelia aurita* Linné; and the polychaete, *Hermodice carunculata* Kinberg. There did not appear to be any close similarity between seabather's eruption and the dermatitis produced by any of the above organisms. Likewise, there is not the slightest evidence to substantiate seabather's eruption as being an allergic dermatitis.

Linuche unguiculata Eschscholtz has been reported, from many sources, as capable of producing stinging sensations to bathers who come into contact with it. Also, many people believe this medusa to be the causative agent of seabather's eruption. On April 9, 1950, however, the writer observed thousands of these medusae in the shallow waters of Miami Beach, and although they were swarming throughout the waters of the bathing beaches where many people were in the water, not one case of seabather's eruption was reported. Several hundred of these medusae were collected and placed in aquaria where they remained alive for several weeks. During this time, many attempts were made to produce a dermatitis, or, at least, a stinging sensation on numerous human subjects. There was no sensation reported by any of the subjects even though the medusae were placed on tender parts of the skin.

Another commonly suggested cause of seabather's eruption has been the larval stages of *Callinectes sapidus* Rathbun. All the larval stages of this crab, as well as those of many other crustaceans, were tried on the skin of various subjects without the slightest sensation reported by any of the subjects.

As no experiments using larval stages of the trematodes were carried out by the writer during the first few months of this investigation, and since Cort (1928) reported a dermatitis characterized by papular eruptions caused by schistosome cercariae, it was decided to investigate the possibility of a member of this class being the causative agent. A comprehensive survey of the literature revealed a great similarity between schistosome dermatitis and seabather's eruption. Aside from the fact that the former eruption occurs predominantly on exposed areas of the skin and the latter occurs predominantly beneath the bathing suit, the two appear to be identical as is shown in Table II.

TABLE II

A Comparison of Seabather's Eruption and Swimmer's Itch (Schistosome Dermatitis)

Seabather's Eruption (Figure 1)	Swimmer's Itch (Figure 2)
1. Results from swimming in salt and possibly in fresh water (see Carroll, W. R. and others, 1947).	1. Results from swimming in fresh water and, as recently shown, from swimming in salt water (see Penner, 1950).
2. Occurs predominantly on those areas of the skin underneath the bathing suit.	2. Occurs predominantly on those parts of the body which are not covered by the bathing suit.
3. Some bathers experience a pricking and itching sensation while still in in the water.	3. Same.
4. Drying seems to favor penetration.	4. Same.
5. Does not occur every year in the same bathing area.	5. Same
6. Once having had the dermatitis, although free of it, does not bring immunity.	6. Same.
7. Localized urticaria-like lesions usually appear first, followed by itching papules some of which may become pustular.	7. Same
8. The dermatitis seldom exceeds two weeks in duration.	8. Same.
9. Not all people bathing in the same area are affected.	9. Same.

In view of the close similarity between the two eruptions, and because schistosome dermatitis is known to be caused by penetration of the skin by non-human schistosome cercariae, it was decided to examine the molluscan fauna of the Miami-Miami Beach area for larval trematodes. After a comprehensive investigation involving over 150 species of mollusks, a total of 15 different species of cercariae were isolated. It is believed that most of these species are undescribed and a more thorough examination will be necessary before such descriptions can be made. However, Table III has been included to show the molluscan host and locality in which each host or cercaria was collected. In order to determine whether any of the cercariae would penetrate skin and cause a dermatitis, each species (with the exception of *Cercaria H*) was tried on the skin of a human volunteer.

During the later phase of the investigation, two possible causative agents of seabather's eruption were isolated. These possible agents are *Cercaria H* (Figure 1) and *Cercaria J* (Figure 2) which were liberated from marine gastropods commonly found in the shallow water areas of south Florida and surrounding areas. The intermediate host of *Cercaria H* is *Nassarius vibex* Say and the intermediate host of *Cercaria J* is *Haminoea antillarum guadalupensis* Sowerby.

Cercaria H, a schisosome cercaria, is characterized by being apharyngeal and having a powerful set of penetration glands and pigmented eyespots. The body is covered with regular rows of spines. As some members of the family Schistosomatidae are known to cause a dermatitis (Cort, 1928; Penner, 1950; and others), it appears quite possible that this species of cercaria may be one of the causative agents of seabather's eruption. Furthermore, the intermediate host of this cercaria, *Nassarius vibex* Say, is one of the most common of the

All photomicrographs have been made of unstained living specimens compressed between cover slip and slide.

FIGURE 1. *Cercaria H* (x127). Schistosome cercaria from *Nassarius vibex* Say.

FIGURE 2. *Cercaria J* (x139). Schistosome cercaria from *Haminoea antillarum guadalupensis* Sowerby.

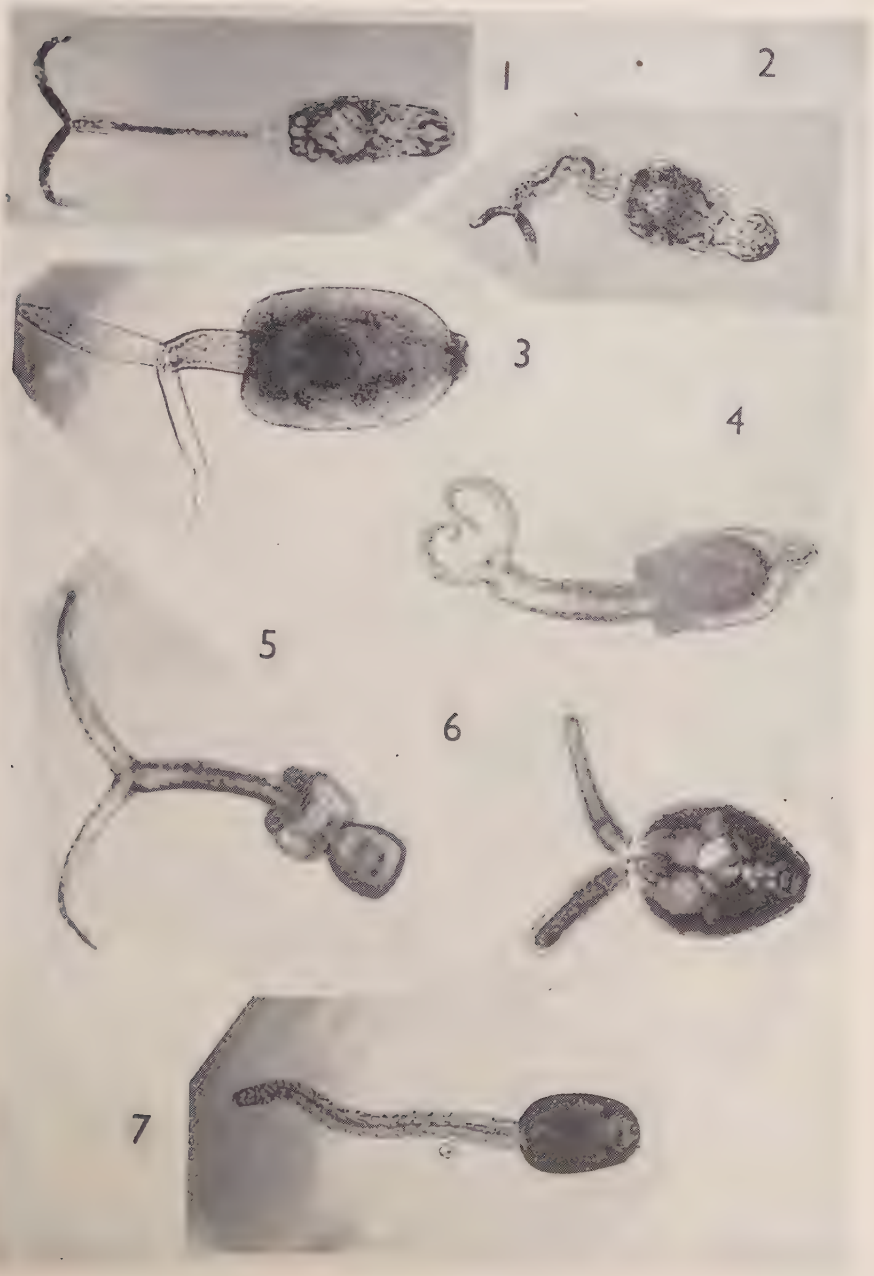
FIGURE 3. *Cercaria A* (x69). Furocercous cercaria from *Cerithium algicola* C. B. Adams.

FIGURE 4. *Cercaria B* (x100). Furcocerous cercaria from *Cerithium algicola* C. B. Adams.

FIGURE 5. *Cercaria C* (x112). Furcocerous cecaria from *Cerithium algicola* C. B. Adams.

FIGURE 6. *Cercaria D* (x44). Furocercous cercaria obtained from plankton haul. Frequently observed by the writer within the body of *Sagitta.*

FIGURE 7. *Cercaria E* (x84). Leptocercous cercaria from *Marginella apicina* Menke.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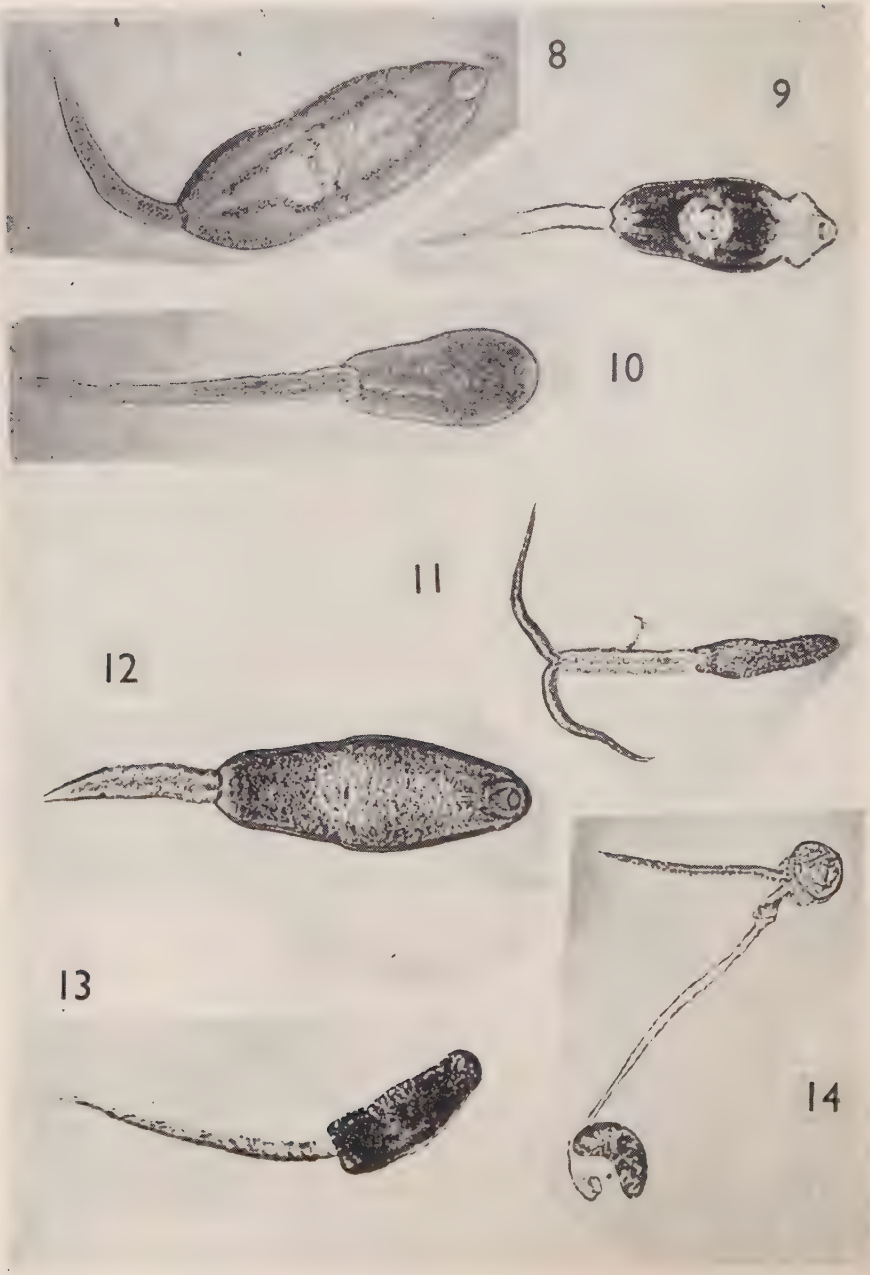
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TABLE III

CERCARIA, MOLLUSCAN HOST, AND LOCALITY IN WHICH HOST OR CERCARIA WAS COLLECTED

Cercaria	Molluscan Host	Locality in Florida	Figure
A	*Cerithium algicola* C. B. Adams	Feathered Bank, Biscayne Bay	3
B	Same	Same	4
C	Same	Same	5
D	Unknown	Gulf Stream, 11 miles east of Miami (plankton haul)	6
E	*Marginella apicina* Menke	Norris Cut, Biscayne Bay	7
F	*Nassarius vibex* Say	Same	8
G	Same	Same	9
H	Same	Same	1
I	*Cerithium algicola* C. B. Adams	Same	10
J	*Haminoea antillarum guadalupensis* Sowerby	Same	2
K	*Nassarius vibex* Say	Same	11
L	*Cerithium algicola* C. B. Adams	Same	12
M	*Nassarius vibex* Say	Same	13
N	*Marginella apicina* Menke	Same	14
O	*Modulus modulus* Linné	South Biscayne Bay	—

marine snails on the Florida beaches. Unfortunately, the single host obtained bearing *Cercaria H* died before tests could be carried out on human volunteers.

Cercaria J is also apharyngeal and is a schistosome cercaria. Specimens of this cercaria were concentrated in petri dishes and tried on the skin of seven human volunteers. Petri dishes containing sea water were used as controls. Within 10 minutes after the petri dishes were applied, each subject reported a definite pricking sensation on the part of the skin bearing the petri dishes containing the cercariae. No sensation was reported from the controls. Three of the seven subjects experienced no further difficulty. Shortly after the application of the cercariae, a fourth subject experienced small red welts which were

FIGURE 8. *Cercaria F* (x155). Leptocercous cercaria from *Nassarius vibex* Say.
FIGURE 9. *Cercaria G* (x104). Echinostome cercaria from *Nassarius vibex* Say.
FIGURE 10. *Cercaria I* (x100). Leptocercous cercaria from *Cerithium algicola* C. B. Adams.
FIGURE 11. *Cercaria K* (x104). Furcocercous cercaria from *Nassarius vibex* Say.
FIGURE 12. *Cercaria L* (x109).Echinostome cercaria from *Cerithium algicola* C. B. Adams.
FIGURE 13. *Cercaria M* (x206).Leptocerous cercaria from *Nassarius vibex* Say.
FIGURE 14. *Cercaria N* (x107). Cystocercous (?) cercaria from *Marginella apicina* Menke.

still evident seven days later although only little itching was reported. Shortly after the cercariae were placed on the three remaining subjects, numerous red welts appeared. These inflammatory papules were accompanied by intense itching which continued intermittently for seven days. The lesions were still evident 10 days later although the itching had almost entirely ceased. These experimentally produced lesions appeared to be identical with those of naturally occurring cases of seabather's eruption.

There appears to be a correlation between the seasonal occurrence of seabather's eruption and the temperature factor controlled time of emergence of *Cercaria J* from its molluscan host. As was mentioned previously, seabather's eruption occurs during the warmer months of the year, and when one takes into consideration the fact that laboratory experiments by the writer have demonstrated that these cercariae will not emerge at temperatures below 22° C., regardless of the light intensity, there appears to be a direct connection here. Also, experiments by the writer have shown that the required time for the cercariae to penetrate human skin is at least four minutes. This may account for seabather's eruption occurring predominantly underneath the bathing suit where a slow drying process takes place. Drying on the exposed areas of the skin may be very rapid and may kill the cercariae before they are able to penetrate.

Conclusions

1. Laboratory experiments have shown that *Cercaria* J, a schistosome cercaria, is capable of producing a dermatitis characterized by inflammatory papules. Experimentally produced lesions appear to be identical with those of naturally occurring cases of seabather's eruption.

2. Seabather's eruption is definitely a seasonal phenomenon in the Miami-Miami Beach area and is most likely to occur between the months of March and August. Likewise, since laboratory experiments have shown that *Cercaria J* does not emerge from its molluscan host at temperatures below 22° C., regardless of the light intensity, it appears likely that this dermatitis would also occur seasonally.

3. The majority of evidence indicates that marine schistosome cercariae are a probable cause of seabather's eruption; but, demonstration of the parasite in a naturally occurring typical case is needed before final proof can be obtained.

REFERENCES

Brackett, Sterling

1940. Pathology of schistosome dermatitis. Arch. Derm. Syph., Wein, *42:* 410-418.

Carroll, W. R., E. C. Hill and H. McElrath

1947. Swimmer's itch in Florida lakes in the Gainesville area. Quart. J. (48) Fla. Acad. Sci., *10*: 98-99.

Cort, W. W.

1928. Schistosome dermatitis in the United States (Michigan). J. Amer. med. Ass., *90*: 1027-1029.

1950. Studies on schistosome dermatitis. XI. Status of knowledge after more than twenty years. Amer. J. Hyg., *52*: 251-307.

Penner, L. R.

1950. *Cercaria littorinalinae* sp. nov., a dermatitis-producing schistosome larva from the marine snail, *Littorina planaxis* Philippi. J. Parasit., *36*: 466-472.

Sams, W. M.

1949. Seabather's eruption. Arch. Derm. and Syph., Wien, *60*: 227-235.

Stunkard, H. W.

1951. Causative agents of swimmer's itch in Narragansett Bay, Rhode Island. J. Parasit., *37*: 26-27.

Thomas, E. J.

1939. Jelly Fish and Portuguese Man-of-War Stings. J. Fla. med. Ass. *26*: 83-87.

Vogel, H.

1930. Hautveranderungen durch *Cercaria ocellata.* Dermato. Wschr., *90:* 577-581.

SHORT PERIOD FLUCTUATIONS OF THE FLORIDA CURRENT FROM GEOMAGNETIC ELECTROKINETOGRAPH OBSERVATIONS[1]

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ABSTRACT

The work of Pillsbury, Parr, and of the recent tanker survey on the short period fluctuations in the Florida Current is reviewed. Recent observations with the Geomagnetic Electrokinetograph in the Miami-Gun Cay section are used to shed some additional light on the problem of these fluctuations. It is shown that the fluctuations along the western edge are sufficiently greater than along the eastern edge for further studies to be restricted to the western half of the stream. It is indicated that fluctuations in the main body of the stream could possibly be related to lunar forces, but that the relations are quite complex. Fluctuations of the counter current appear to be of a tidal origin.

INTRODUCTION

It is the purpose of this paper to present the findings of one year's work with the Geomagnetic Electrokinetograph on the section of the Florida Current between Miami and Gun Cay, Bahamas. It is its further purpose to show the relation between the results of this work and previous studies on the short period variations over this same section.

The author would like to take this opportunity to express his gratitude to Dr. F. G. Walton Smith, Director of the Marine Laboratory, for his work in setting up the project, and for his kind assistance throughout the entire project; to Dr. Ilmo Hela for his many suggestions and advice on the project; and to other members of the Laboratory who have at various times assisted with the work. Particular thanks are due to Von Arx for his invaluable advice and suggestions.

In the classic work of Pillsbury (1890), data obtained on the cruise of the *Blake* were used in a study of short period variations in the Florida Current at the Miami-Gun Cay section. Pillsbury said: "Following the declination of the moon, the velocity of the stream at any given point is accelerated or diminished, but while it is running faster at one place, at another it is running slower. It is in fact a reduction in velocity at the sides accompanying an increase in velocity at the axis, and the reverse, or in effect, an alternate expansion and contraction of the stream width. This is not marked on the east side of the Straits

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of Florida, and, as will be seen later, is hardly to be expected. It is very marked on the west side of the stream." What Pillsbury has said can best be seen in Figure 1, prepared from the data of this report. At high declination, the speed of the current at the western edge is relatively high and, in fact, almost as high as at the axis. The shear on the western side is small. The axis of the stream appears to be very near the middle of the Straits. At low declination, a small current is evident at the western edge. A very steep western shear is also apparent. The axis is west of the middle of the section. The eastern shear and current at the eastern edge are essentially the same at all declinations. Pillsbury also remarked that the stream varied with the transit of the moon, having a principal maximum nine hours before the moon's upper transit, and a lesser secondary maximum nine hours before the moon's lower transit. This variation was apparently true of the average

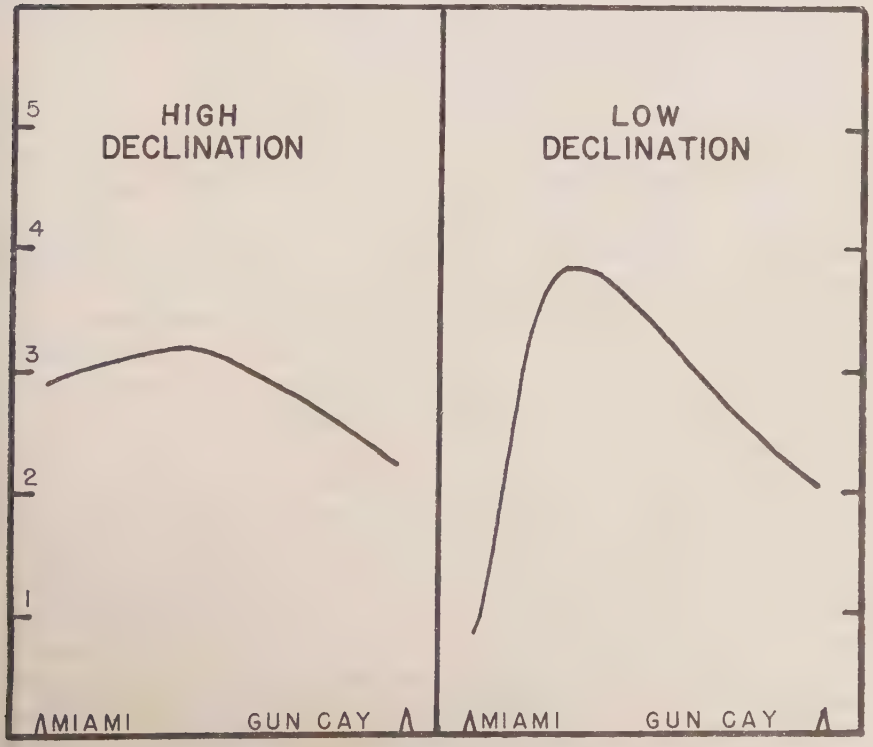

FIGURE 1. Current profiles at the Miami-Gun Cay section at high and low lunar declination taken from the data of Pillsbury.

flow across the section rather than of velocities at specific points such as the counter current region, shear zones or axis.

The next important work on short period fluctuations of this section was by Parr on the *Atlantis* in 1937. The data were collected from five stations across the stream, each occupied for a period of 24 hours. Results from such a short time of observation could hardly be conclusive. However, they are indicative. Parr himself stated: "The question of the finer details of periodicities in the profile here discussed is so complicated by the occurrence of special oceanographic events during the period of observation, that it can only be dealt with in regard to its grossest features, until more data may be made available through future research." Parr's figures were derived from dynamic computations in which he compared adjacent stations, and were confirmed by surface observations with a taffrail log. His results show a 12-hour lunar periodicity in velocity which is most marked at the western edge and almost indiscernible at the eastern edge, and thus he concluded that lunar forces play an important, although complicated, part in the changes of the current.

The results of the Tanker Survey (1952) represented the most recent work to date on this portion of the Florida Current. This work in general did not deal with so-called "short" period variations, with one exception. The variation of the current speed, at a point a little east of the axis of the stream, in the vicinity of Jupiter, Florida, with lunar phase was plotted. This plot showed that the current varied from a small maximum two or three days after spring tide through a minimum seven days after spring tide to a principal maximum eleven days after spring tide. The range of variation was from approximately 2.3 knots to approximately 2.8 knots. This survey also indicated that the predominant position of the stream at the Miami section was further west in the summer than in winter.

The development of the Geomagnetic Electrokinetograph by Von Arx of Woods Hole Oceanographic Institution has provided oceanographers with a new tool for the study of ocean currents. This tool is unique in that it allows one to obtain a continuous record of the current through which a vessel is passing at normal cruising speed. This then makes it possible to obtain a picture of a given current in much less time than was previously possible. Such characteristics made this instrument ideal for reopening the problem of the short period fluctuations of ocean currents. Availability of this instrument made it possible to undertake a study of the Florida Current at the Miami-Gun

Cay section early in 1951. The plan of operation was initiated by F. G. Walton Smith with the assistance of Charles Dawson. The present writer has been in charge of the project since the middle of June, 1951.

Methods

The measurements were made by starting at the Miami sea buoy and proceeding to Gun Cay light, making electrode zero fixes every hour by running for five minutes south, five minutes north, and then back on course. This gave not only the electrode zero, but also the east-west component of the stream. By this method of study a continuous graph of the northerly component of the stream could be made, in addition to knowing accurately the direction of the stream at several points across the Straits.

It is necessary that the position of the vessel be known as accurately as possible at all times when making measurements with this instrument. Since Loran is not suitable in the area, it was planned that Radar be used. Due to delay in the availability of this equipment, accurate navigational fixes were not possible during the first part of the work. It was, therefore, necessary to use D. R. as accurately as we could.

Some electrode instabilities caused the loss of a few trips. These instabilities were traced to the method of connecting on board ship. We are greatly indebted to Mr. Von Arx whose suggestions and advice enabled us to alleviate these difficulties. As a result, 18 crossings were made during the past year. This is, however, enough to show clearly the complexities of the stream and to indicate improved methods of attack.

Several sources of error enter into a consideration of the results. The K factor as defined by Von Arx (1950), the designer of the Geomagnetic Electrokinetograph, is the ratio of the actual current to the current computed from the electrical signal measured by the GEK. According to present theory, the velocity of the water moving at right angles to the direction of motion of the vessel is equal to the electrical signal recorded by the GEK divided by the vertical component of the earth's magnetic field and multiplied by a constant to correct the units. However, other factors than the movement of the water modify the electrical field. Among these are the conductivity of the sea bottom and the vertical distribution of velocity. These effects, which cannot at the present time be accurately evaluated, tend to make the electrical signal smaller than is predicted by theory, and thus increase the

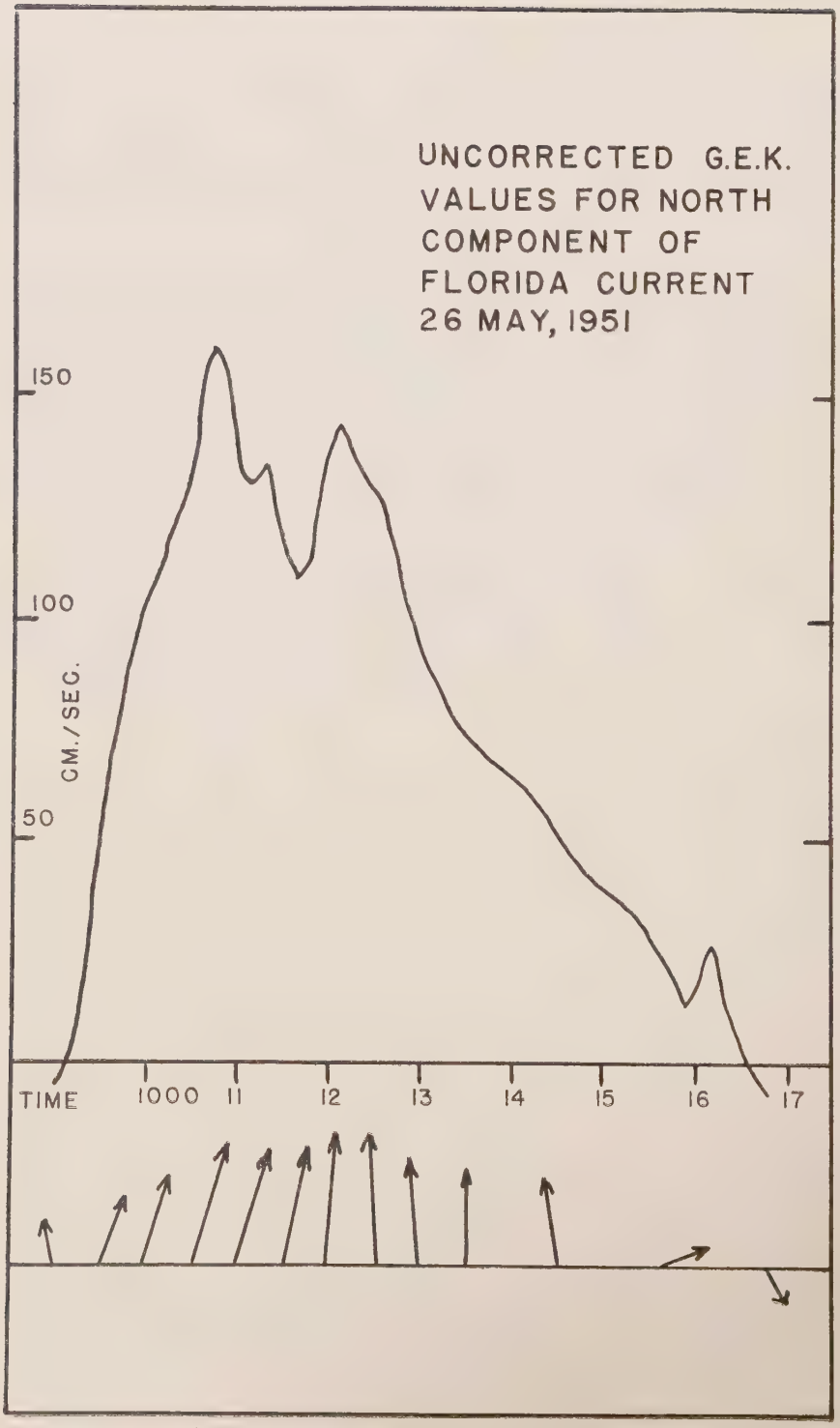

FIGURE 2. A typical profile at the Miami-Gun Cay section taken from GEK data not corrected for the average K factor. The arrows at the bottom indicate the direction of the current with the top of the page taken as north.

value of the K factor over what is normally found in the open ocean.

The average K factor was found by adding, vectorialy, the GEK current vectors, computed for each current fix, and dividing the magnitude of the resultant by the total time of the trip. This was then compared with the average drift found by dividing the total drift vector magnitude by time for the trip. This method was found to be satisfactory since the GEK drift vector and the actual drift vector were in good agreement as to direction. This procedure when applied here can only give an average K factor for the crossing which is not applicable at every point in the stream. In addition, the average K factor varies in this location over a wide range.

In addition to the regular crossings, one 48-hour station with continuous GEK records has been made with several more planned for the future. The 48-hour station was carried out by running east from the Miami sea buoy for 40 minutes, south for 15 minutes, and north for five minutes in order to maintain a position fairly constantly in line with the sea buoy. From here the vessel proceeded west for 40 minutes with a similar dogleg at the western end. This procedure gave a fairly complete picture of the counter current and the western shear zone. These transects extended very near the axis, the speed of the vessel being a little better than eight knots. Graphs of the north component for each transect were made from the GEK records. In this case no attempt has been made to evaluate the K factors since the purpose of the station was to study diurnal and semi-diurnal fluctuations. From the northerly component graphs, plots of the counter current against time, shear against time, maximum current against time. direction in the counter current zone against time, direction of maximum current against time, and distance of the maximum current from the Miami sea buoy against time were made.

Results and Comparison

Figure 2, a GEK graph of the north component of the Florida Current, represents a typical example of the data obtained from a single crossing. This graph was plotted from GEK values taken at 15-minute intervals. Below the graph are current arrows for each fix. This graph has a time abscissa which is proportional to the distance. This graph indicates the location at which a particular velocity was found, but one must remember that the current measured on one side of the stream may not have been the same when the current was being measured at the other side.

Figure 3 is the superposition of all the GEK graphs with K factors between 1 and 2.9, with distance substituted for the time as an abscissa. This figure shows that variation is much more predominant on the western side of the stream. These graphs are not corrected for average K factor.

Figure 4 is the average of the GEK values plotted for the sections shown in Figure 3, together with their standard deviation. The standard deviation curve shows more clearly that the variation on the western side is much more pronounced. The standard deviation of the eastern and western gradients are shown in Table II. This gives a value of 6.35 for the western side and a value of 1.47 for the eastern side. This then is quite conclusive evidence that the variations are greater on the west.

The variability of the average K factor shows distinctly that the true K factor at a particular point varies with time and should, therefore, be known as a basis for these computations. This is, unfortunately enough, not the case. The average K factors are shown in Table I for each crossing. Several details in the GEK graphs seem to indicate at least a qualitative correspondence in general distribution of velocity and location of shear and counter current zones.

With the above reservations in mind, the GEK observations show

TABLE I

AVERAGE K FACTORS FOR ENTIRE CROSSINGS

Date of Crossing	*K Factor*
ii-14-51	2.17
ii-25-51	2.35
iii-10-51	1.78
iii-31-51	1.39
iv-14-51	2.13
iv-15-51	3.00
iv-28-51	1.71
iv-29-51	1.61
v-26-51	1.96
v-27-51	1.94
vi- 1-51	1.81
vii-11-51	1.22
vii-12-51	2.32
viii- 9-51	1.23
viii-11-51	2.00
viii-22-51	1.54
xi-15-51	4.06
xi-15-16-51	2.46
i-26-52	2.91

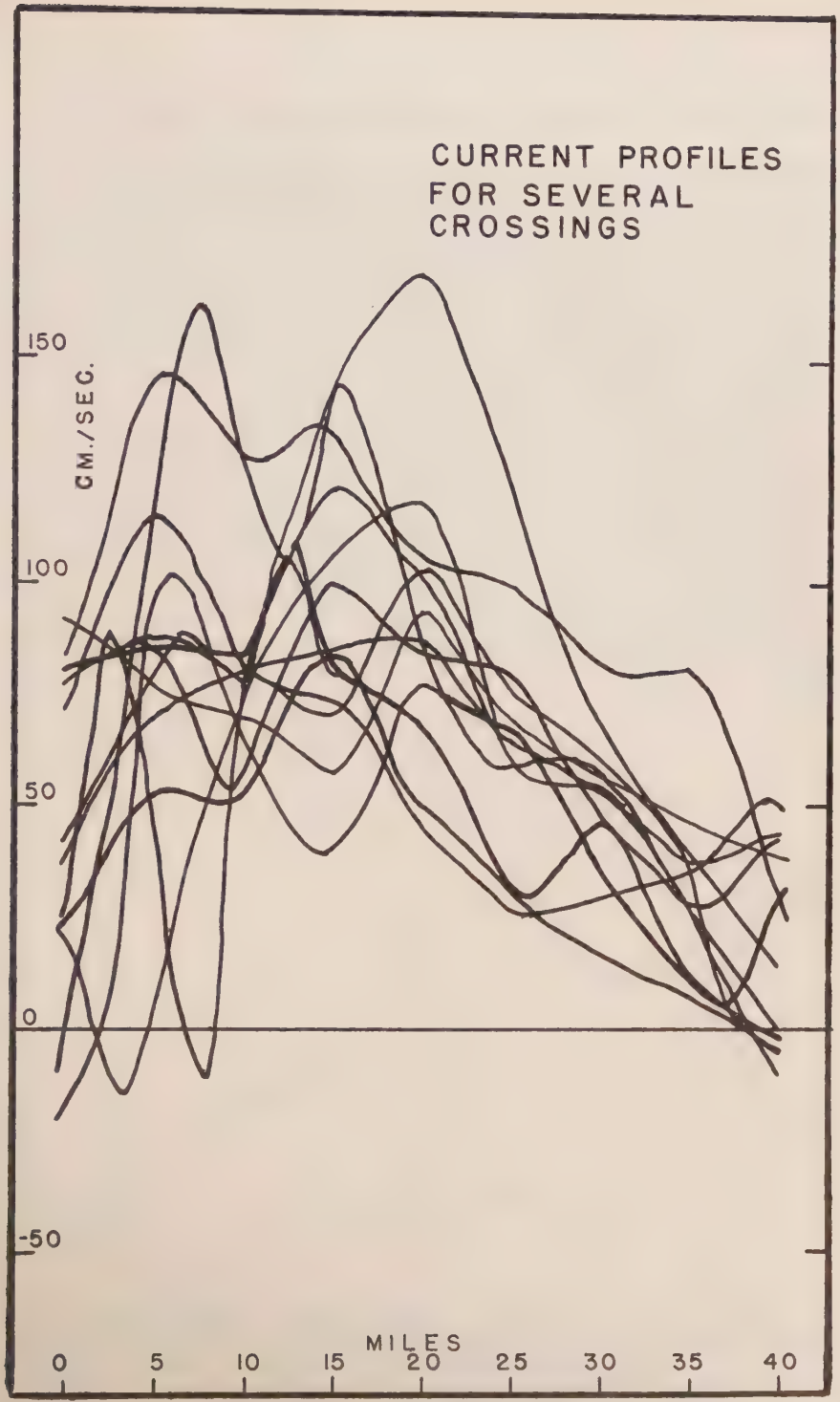

FIGURE 3. The superposition of 13 profiles taken from GEK data for crossings whose K factors did not exceed 2.9.

certain features. The fluctuations along the eastern edge do not appear to be very great, just as Pillsbury suggested. In the light of the theoretical work of Haurwitz and Panofsky (1950) on the cyclonic and anticyclonic shear, this appears to be quite reasonable. Table II shows values of the eastern and western shear. In general the western shear is quite great while the eastern shear is not so great and varies over a much smaller range. The variations for the western side show a great variation in the degree of shear while the variations on the eastern side are much smaller.

It is worthwhile to mention at this point that, according to the Wake Stream theory developed by Dr. Rossby, the eastern velocity gradient should have as its upper limit the value of Corioli's parameter for that latitude. The maximum value of the eastern gradient shown above is 6.10×10^{-5} cm. sec. $^{-1}$ cm. $^{-1}$. The value of Corioli's parameter for this latitude is 6.55×10^{-5}. This agreement is excellent.

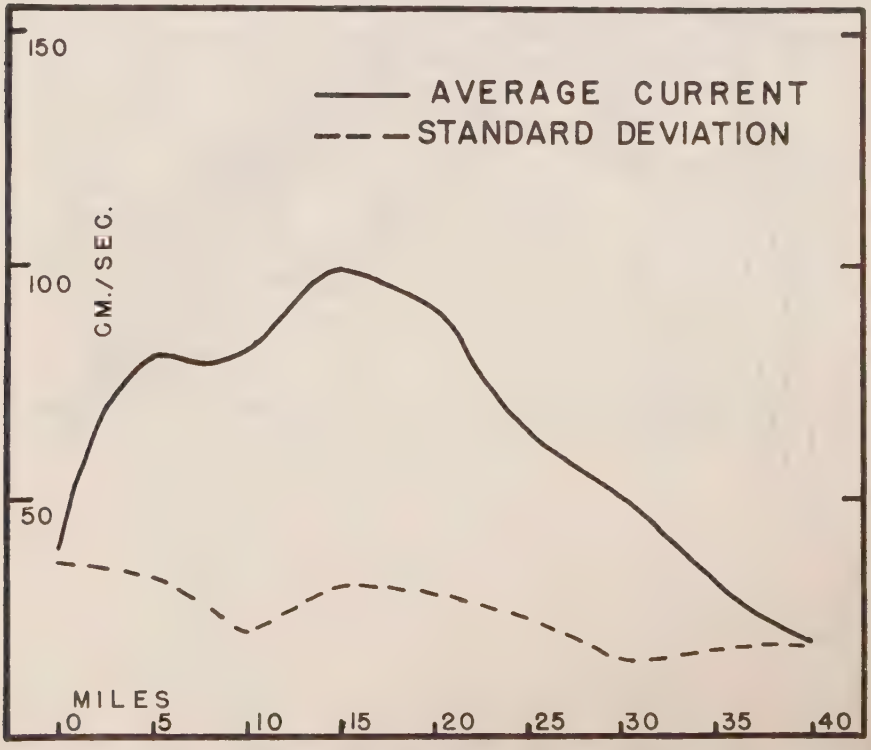

FIGURE 4. An average profile computed from Figure 3, together with the standard deviation computed for each 5 miles across the section.

The axis of the current moves eastward and westward but with no discernable regularity. The maximum velocity was plotted against the declination of the moon (Figure 5). This does not seem to confirm the corresponding suggestion of Pillsbury. In addition, the maximum velocities from those 18 crossings were plotted against the lunar transit (Figure 6). This, too, shows no apparent correlation. At this point it would appear that the lunar forces had very little to do with the fluctuations in the Florida Current. It must be remembered that these forces may exhibit themselves in a very complex manner. In order to imagine this a little more clearly, it will be necessary to remember that all averages taken across the stream are not only space averages but time averages as well. This time factor would have only a minor influence if the current did not vary greatly over a period of 36 hours or more; however, this is not the case. The 48-hour station shows that in the counter current zone the vector changes from maximum north to maximum south in as little as four hours. The current near the axis varies in the same time by as much as 100% of its smaller value. Such high speed changes mean that averaging over a period of four hours would involve the time rate of change as well

TABLE II

VELOCITY GRADIENTS IN CM. SEC.$^{-1}$ KILOMETERS^{-1}
(Values corrected for the average K factor)

Trip	*Western Gradient*	*Eastern Gradient*
101A	12.4	3.3
101B	3.87	4.32
108	8.6	3.92
111B	13.7	3.78
114A	12.0	3.23
114B	10.6	3.70
117	5.06	1.95
123A	1.01	2.71
123B	3.34	5.45
126A	0.078	0.624
126B	15.5	6.10
128A	0.293	1.46
138A	5.92	5.66
138B	10.3	4.52
203	24.7	5.00
205A	0.93	3.48
205B	7.26	3.09
Standard deviation	6.35	1.47
Average	7.98	3.66

as the distance rate of change. Another factor which might serve to obscure a lunar periodicity is the fact that the tidal wave moving in the Straits of Florida might not, and in fact probably does not, have a simple straight line front or crest. Let us suppose that the fluctuations in the Florida Current are due to tidal forces. Now suppose that the tidal wave moves South through the Florida Straits in a "U" shape with the "U" open to the North. Then we must see that the maximum tide reaches the middle of the stream at the Miami-Gun Cay section before it reaches the edges at the same section. Let us further assume that the velocity of the stream at a particular point follows the derivative of the tidal height variation. In addition, suppose that the flow in the middle of the stream affects the counter current region in a fashion similar to that suggested by Rossby. It is apparent that, in the light of the hydrographic confusion introduced above, it might

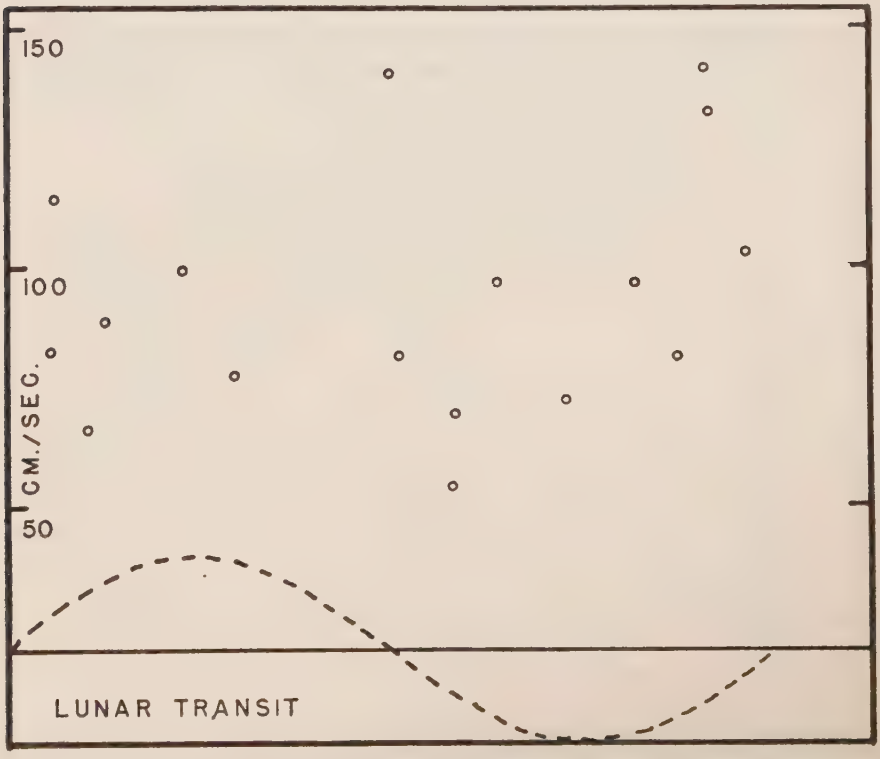

FIGURE 5. Axis currents from GEK observations plotted against their phase of the lunar transit.

be rather difficult to observe the periodicities from scattered observations.

An attempt was made to determine the shape and movement of the tidal wave front from a cotidal plot of the area. There were many stations along the Florida coast but a decidedly insufficient number along the Bahama Banks. It is apparent, however, that the tidal wave does move southward towards Cay Sal Banks and that it has somewhat of a "U" shape, probably skewed toward the Florida coast (Figure 7). It is hoped that in the future more tidal information may be available from the eastern edge of the Florida Current and that this information may then be more accurately determined.

The above mentioned variations, together with other variations, make it very nearly impossible to discover, from scattered measurements, any regularity at the present time. Wind also causes a certain amount of irregularity, the evaluation of which would be at least very

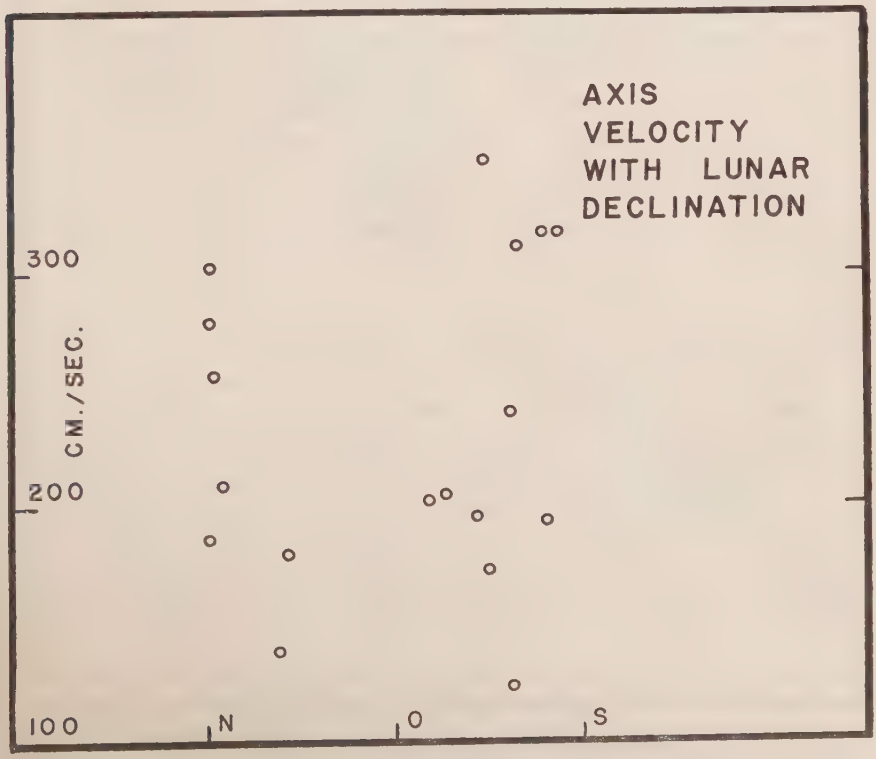

FIGURE 6. Axis currents plotted against their phase of the lunar declination.

tedious, perhaps impossible, due to the complexity of the topography. In the light of this, it becomes necessary to change one's method of study as will be described later in this paper.

Analysis of the 48-Hour Station

The data collected at the 48-hour station are very interesting but are insufficient as a tool for completely describing periodicities. When several of these stations have been run, it is hoped that some periodicities will be accurately evaluated. Figure 8 is a plot of the maximum currents found on each transect against time. With this is a graph of lunar transit. The correlation here is poor. This could, however, be due to wind conditions and the fact that all the points chosen were not at the same geographical location. The location varies over a few miles north and south and probably less than one mile east and west. It was noted that when running south the east-west component was

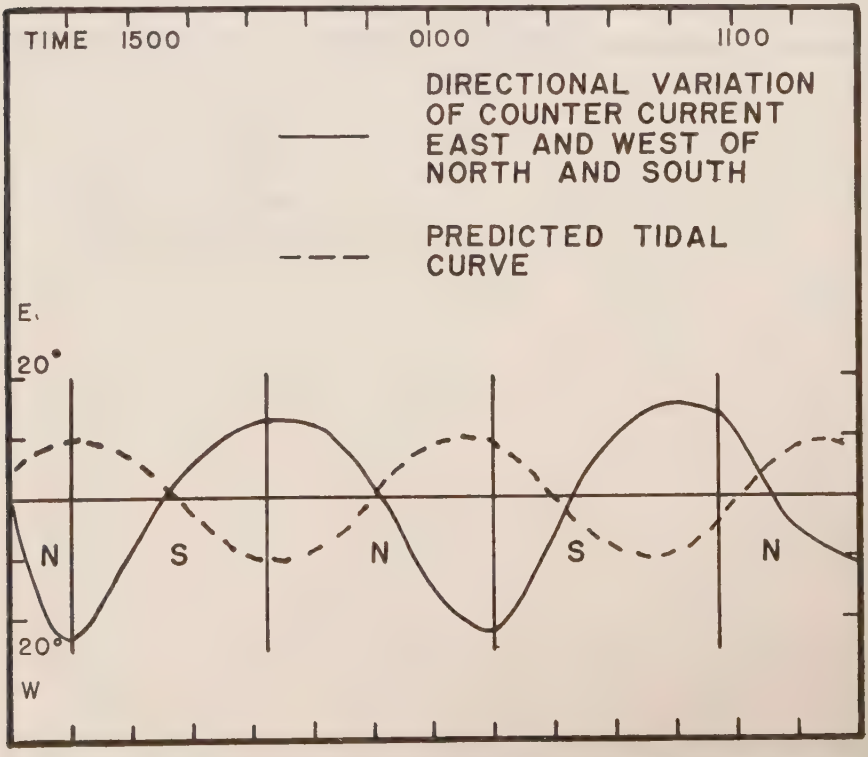

Figure 7. A probable tidal movement for the Florida Straits showing the apparent shape of the wave front.

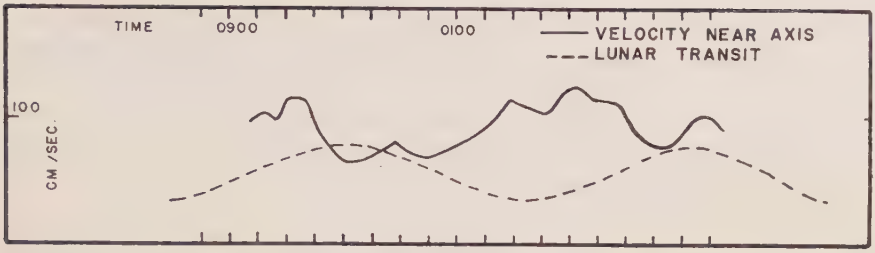

FIGURE 8. Plots of the velocity near the axis, together with the lunar transit for the same period and of the velocity in the counter current zone, together with the derivatives of the predicted tidal heights for the same period. Both plots were made from data taken on the 48-hour station with the GEK.

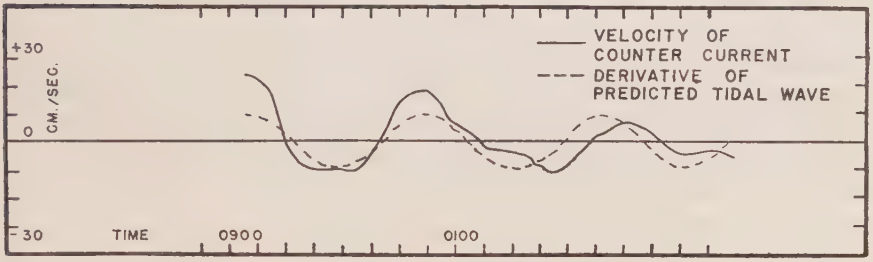

FIGURE 9. The directional variation of the current in the counter current zone. The figure is divided by lines indicating the period of generally northerly and southerly flow. The dotted curve is the predicted tidal curve for the same period.

varying over a small range at a rather high frequency. This occurred only at the seaward fix, and was not regular in appearance. This small variation was attributed to a rapid and small directional variation in the current vector.

Figure 9 represents the counter current plotted against time for the 48-hour station. The derivative of the predicted tide at Miami harbor entrance is also plotted in the same figure. The derivative was used rather than the tidal heights because it is felt that the counter current might be greatly influenced by the semi-diurnal tidal wave and would, therefore, follow a velocity rather than a displacement curve. The counter current seems to follow this tidal derivative curve very well. It is hoped that later work will make this relation clearer.

Figure 7 represents the direction of the counter current against time, together with the predicted tidal waves. The time is also divided by heavy vertical lines into the periods of northerly or southerly flow.

Since the direction appears to vary only 15° east of north or south and 25° west of north and south, it is evident that, if the direction does pass through all points of the compass, it must go from 15° east of south to 15° east of north very rapidly. The same must also be true on the western change. The direction also changed always in a counter clockwise or cyclonic sense.

Summary

It is evident that there is a great possibility that lunar periodicities may be described accurately. It will be necessary to change the present method of study so as to avoid some of the difficulties presently encountered. GEK measurements only as far east as the axis, or a little further, would be sufficient since the variations east of this point are relatively small. These observations should be made as frequently as economic conditions will allow, and should be continued for at least one year. It is of utmost importance that the position of the vessel be accurately known at all times in order to know the regional distribution of the K factor. In addition to the above mentioned observations, it would be wise to run 48-hour stations, as previously described, at frequent intervals during the year.

Conclusions

1. Short period fluctuations are most apparent in the western half of the Florida Current at this location. The currents of the eastern half also vary but with smaller amplitude.

2. The variations are of a very complex nature and of sufficient amplitude to cast doubt on the use of previous work as a basis for predicting other than averages over a month or more.

3. The shear zones appear to behave generally in accord with the Wake Stream theory. However, nothing has been done to compute the predicted effects as the accuracy of measurement does not justify such computations.

4. There is strong evidence of a tidal influence on the counter current region. This is based, however, on the results of one 48-hour station alone.

REFERENCES

Haurwitz, B. and H. A. Panofsky

1950. Stability and meandering of the Gulf Stream. Trans. Amer. Geophys. Union, *31*(5):723-731.

Parr, A. E.

1937. Report on hydrographic observations at a series of anchor stations across the Straits of Florida. Bull. Bingham Oceanogr. Coll. *6*, Art. *3*:1-62.

Pillsbury, J. E.

1890. The Gulf Stream. U. S. Coast and Geodetic Survey. Reprint No. 10.

Rossby, C. G.

1937. On the mutual adjustment of pressure and velocity distribution in certain simple current systems. J. Mar. Res., *1*(1):15-28.

U. S. Navy Hydrographic Office

1952. Tanker survey of the Gulf Stream. U. S. Navy Hydrographic Office Chart No. 1400, March, 1952.

Von Arx, William S.

1950. An electromagnetic method for measuring the velocities of ocean currents from a ship under way. Pap. Phys. Oceanogr. Meteorol., *11*(3): 1-62.

REGIONAL BIBLIOGRAPHY FOR 1951

The scope of the bibliography is limited in general to the area which includes the southeastern United States, the Gulf of Mexico, and the Caribbean, but papers of more general interest may be listed in cases where they have some special significance to the area.

The degree of comprehensiveness of the bibliography is to a large extent dependent upon the cooperation of workers in the Marine Sciences of this area. *It is therefore hoped that individuals and organizations will aid by sending copies of all relevant publications to the Editor.* Any omissions brought to the attention of the Editor will be included in subsequent issues.

It has been found convenient to use a modification of the classification used by the Journal du Conseil Bibliography for present purposes.

The Editorial staff wishes to acknowledge the valuable assistance given by a number of investigators in compiling the bibliography.

GENERAL

Institutions

BEARS BLUFF LABORATORIES

1951. Progress Reports. 7, 8, 9, 10. Duplicated.

HYDROGRAPHY

Apparatus and Methods

OLSEN, F. C. W.

1951. A plastic envelope substitute for drift bottles. J. Mar. Res., *10* (2): 190-193.

Surveys and General

TEXAS A. & M. COLLEGE, DEPARTMENT OF OCEANOGRAPHY

1951. Hydrographic survey of Corpus Christi Bay. Periodic Prog. Rep. Reynolds Metals Company.

1951. Oceanographic and meteorological survey of the Gulf of Mexico. Periodic Prog. Rep. Office of Naval Research.

1951. Physical oceanography of shallow waters. Periodic Prog. Rep. American Petroleum Institute.

Temperature

ADAMS, RICHARD M. AND ERNEST F. SORGNIT

1951. Comparison of summer and winter sea temperatures, Gulf of Mexico. Texas A. & M. College, Department of Oceanography.

LEIPPER, DALE F. AND RICHARD M. ADAMS

1951. Analysis of bathythermograms, Latitude 25°30′ N, Longitude 85°00′ W, to Florida coast. Texas A. & M. College, Department of Oceanography. Mimeogr. Rep.

STOMMEL, HENRY AND ALFRED H. WOODCOCK

1951. Diurnal heating of the surface of the Gulf of Mexico in the spring of 1942. Trans. Amer. Geophys. Un., *34,* (4): 565.

Currents and Circulation

Fuglister, F. C.
1951. Annual variations in current speeds in the Gulf Stream system. J. Mar. Res., *10* (1): 119-127.

Leipper, Dale F.
1951. General nature of the ocean currents of the Gulf of Mexico. Texas J. Sci., *3* (1): 41-44.

The Marine Laboratory, University of Miami
1951. The Florida Current investigation. Periodic Prog. Rep. Office of Naval Research.

Estuarine Problems

Farmer, Harlow G.
1951. An experimental study of salt wedges. Tech. Rep., Reference No. 51-99. Woods Hole Oceanographic Institution.

Stommel, Henry
1951. On the physical nature of estuarine circulation. Woods Hole Oceanographic Institution, Contrib. No. 597. A paper presented at the Symposium on Estuarine Ecology, A.A.A.S., Philadelphia, December 30, 1951. Manuscript.

Waves

Fleming, R. H. and C. C. Bates
1951. The engineering application of sea and swell data. Proc. First Conference on Coastal Engineering: 88-97.

Geography and Geology of Sea Floor

Applin, Paul L.
1951. Preliminary report on buried pre-Mesozoic rocks in Florida and adjacent states. U. S. Geol. Surv., Circ. No. 91, pp. 1-28.

Bennett, H. S. and P. Martin-Kaye
1951. The occurrence and derivation of an augite-rich beach sand, Grenada, B. W. I. J. Sediment. Petrol., *21* (4): 200-204.

Bush, James
1951. Rock from the Straits of Florida. Bull. Amer. Assoc. Petrol. Geol., *35* (1): 102-106.

Haeberle, Fred R.
1951. Gulf Coast Geosyncline. Texas J. Sci., *3* (3): 368-375.

Jordan, G. F.
1951. Continental slope off Apalachicola River, Florida. Bull. Amer. Assoc. Petrol. Geol., *35* (9): 1978-1993.

Lee, C. S.
1951. Geophysical surveys on the Bahama Banks. J. Inst. Petrol., *37* (344): 633-657.

Lowman, Shepard W.
1951. The relationship of the biotic and lithic facies in recent Gulf Coast sedimentation. J. Sediment. Petrol., *21* (4): 233-237.

MacNeil, F. Stearns
1951. Pleistocene shorelines in Florida and Georgia. U.S. Geol. Surv., Prof. Pap. 221-F, pp. 95-107.

Newell, Norman D.
1951. Organic reefs and submarine dunes of oolite sand around Tongue of the Ocean, Bahamas. Abst. Geol. Soc. Amer., *62* (12)pt.2: 1466.

Newell, Norman D., J. Keith Rigby, Arthur J. Whiteman, and John S. Bradley
1951. Shoal-water geology and environments, eastern Andros Island, Bahamas. Bull. Amer. Mus. Nat. Hist., *97*, Art. 1: 1-30, *Pls.* 1-8.

Weaver, Paul
1951. Continental shelf of Gulf of Mexico. In Future petroleum provinces of North America, Bull. Amer. Assoc. Petrol. Geol., *35* (2): 393-398.

Williams, Harry F.
1951. The Gulf of Mexico adjacent to Texas. Texas J. Sci., *3* (2): 237-250.

Meteorology

Gentry, R. C.
1951. Forecasting the formation and movement of the Cedar Keys hurricane, September 1-7, 1950. Monthly Weather Rev., *79* (6): 107-115.

Glenn, A. H.
1951. Applications of meteorology and oceanography in marine industry on the Gulf of Mexico. Texas J. Sci., *3* (2): 191-201.
1951. Economic considerations of certain weather and oceanographic problems arising in the petroleum industry. Oklahoma City, October, 1951.

Glenn, A. H. and R. W. James
1951. Use of the wave height vs. operational efficiency relationship in planning offshore gravity meter exploration. Proc. Conference on Coastal Engineering, Houston, November, 1951.

Gerhardt, John R.
1951. Temperature and moisture soundings over the Gulf of Mexico for March 1949. Trans. Amer. Geophys. Un., *32* (1): 15-25.

Hildreth, W. W., Jr.
1951. Weather radar and offshore operations. Petrol. Eng., July, 1951.

Moore, Paul L. and Walter R. Davis
1951. A preseason hurricane of subtropical origin. Monthly Weather Rev., *79* (10): 189-195.

Norton, Grady
1951. Hurricanes of the 1950 season. Monthly Weather Rev., *79* (1): 8-15.

Shisler, K.
1951. An initial solution to the hurricane problem of the offshore oil operator. Bull. Amer. Meteor. Soc., March, 1951.

U. S. Weather Bureau
1951. Analysis of winds over Lake Okeechobee during tropical storm of August 26-27, 1949. Hydrometeorological Rep. No. 26, Washington, January, 1951. 80 pp.

Surface Phenomena

Texas A. & M. College, Department of Oceanography
1951. Transfer processes operating at the ocean boundaries. Periodic Prog. Rep. Office of Naval Research.

Special Problems, Erosion, etc.

Leipper, Dale F., Warren C. Thompson, Paul L. Horrer, Robert O. Reid, Claude E. Zobell, and T. R. Folsom
1951. Oceanographic analysis of marine pipe line problems (Atchafalaya Bay, Louisiana and adjacent continental shelf area). Texas A. & M. College, Department of Oceanography, June, 1951. Mimeogr.

The Marine Laboratory, University of Miami
1951. Ambient sound and scattering layer investigations. Prog. Rep. U. S. Navy Bureau of Ships.
Reid, Robert O.
1951. Oceanographic considerations in marine pipe line construction. Gas Age, April 26, 1951.
Texas A. & M. College, Department of Oceanography
1951. Development of oceanographic information needed for offshore operations. Periodic Prog. Rep.
1951. Wave forces on hinged piling in shallow water. Periodic Prog. Rep. U. S. Navy Bureau of Yards and Docks.

PLANKTON

Zooplankton

Pierce, E. Lowe
1951. The occurrence and breeding of the Chaetognatha along the Gulf coast of Florida. Abstract. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3:* 126-127.
1951. The Chaetognatha of the west coast of Florida. Biol. Bull., *100* (3): 206-228.
Voss, Gilbert L.
1951. Further description of *Octopus Burryi* Voss with a note on its distribution. Bull. Mar. Sci. Gulf & Caribbean, *1* (3): 231-240.

BENTHOS

Distribution and Ecology

Butler, Philip A.
1951. Erosion and the littoral benthos. Shore and Beach, *19* (1).
Ladd, Harry S.
1951. Brackish water and marine assemblages of the Texas coast with special reference to mollusks. Publ. Inst. Mar. Sci., Texas, *2* (1): 125-164.
Phleger, Fred B. and Francis L. Parker
1951. Ecology of Foraminifera, northwestern Gulf of Mexico, Pts. I and II. Geol. Soc. Amer., Mem. 46, 152 pp., 22 figs., 37 tables, 22 pls.
Post, Rita J.
1951. Foraminifera of the South Texas coast. Publ. Inst. Mar. Sci., Texas, *2* (1): 165-176.

FISH

Systematics, Morphology and Development

Rivas, Luis Rene
1951. A preliminary review of the western North Atlantic fishes of the family Scombridae. Bull. Mar. Sci. Gulf & Caribbean, *1* (3): 209-230.
Springer, Stewart
1951. Correction for "A Revision of North American Sharks Allied to the genus *Carcharhinus.*" Copeia, August 31, 1951 (3): 244.

Distribution and Ecology

The Marine Laboratory, University of Miami
1951. Bluefin Tuna investigations. Prog. Rep.
Gunter, G. and H. H. Hildebrand
1951. Destruction of fishes and other organisms on the South Texas coast by the cold wave of January 28—February 3, 1951. Ecology, *32* (4): 731-736.

FISHERIES

Commercial Fisheries. Landing Statistics

Broadhead, Gordon
1951. The organization of the Florida marine fisheries statistical system. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3:* 114-117.

Lueth, Francis X.
1951. The organization of "Alabama Landings." Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3:* 111-114.

Technology

Crowther, H. E.
1951. Control of fish spoilage by icing and freezing. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3:* 85-88.

Fieger, E. A.
1951. Cause and prevention of Black Spot on shrimp. Ice & Refrigeration, April, 1951, pp. 49, 50, 64.
1951. Refrigeration of Gulf shrimp, with special reference to the cause and prevention of Black Spot. Proc. Amer. Warehousemen's Assoc., *60:* 98-102.

Hardison, R. P.
1951. Florida's seafood sanitation program. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3:* 106-110.

Idyll, C. P.
1951. Black discoloration in shrimp. Spec. Serv. Bull. No. 4., The Marine Laboratory, University of Miami.

Economics, Distribution, Regulation

Anderson, A. W.
1951. Problems of the commercial fishing industry. Proc Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3:* 135-136.

Beasley, Ernest A., Jr.
1951. Some economic aspects of charter boat fishing in the Miami area. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3:* 58-64.

Butler, Philip
1951. Report to the Gulf States Marine Fisheries Commission. Southern Fisherman, *9* (2), November.

Heydecker, Wayne D.
1951. The Atlantic States Marine Fisheries Commission: A progress report. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3:* 119-125.

James, M. C.
1951. Fishery administrators' problems. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3:* 65-68.

Kahn, Richard A.
1951. What are the most significant economic trends in the Gulf and Caribbean fisheries? Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3:* 139-140.

Meyer, Max
1951. The outlook for breaded shrimp and similar products. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3:* 15-17.

Robas, John S.
1951. What does the future hold for the independent boat owner? Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3:* 18-22.

Taylor, Francis
1951. The future of the red snapper fishery. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3:* 11-13.

Thomas, Bert E.
1951. The Gulf States Marine Fisheries Commission: A progress report. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3:* 117-119.

Truitt, R. V.
1951. Problems of fishery management in Maryland. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3:* 76-78.

Van Gelderen, Philip
1951. Report on the fisheries of Surinam. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3:* 55-58.

Vathis, George A.
1951. Problems of fishery administration in Florida. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3:* 71-76.

Wallace, David H.
1951. Problems of fisheries administrators in the Atlantic States. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3:* 69-71.

Wegmann, A. J.
1951. Problems of administration and transportation in the wholesale fisheries industry. Proc. Gulf & Caribbean Fish Inst., 3rd Annual Session, *3:* 13-14.

Hatcheries, Cultivation, etc.

Lunz, G. Robert
1951. A salt water fish pond. Contrib. No. 12, Bears Bluff Laboratories, 12 pp., 2 figs.

Vessels and Gear

Lawrence, Ewing, Jr.
1951 The use of echo sounders in fisheries. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3:* 88-95.

Grounds

Carlson, C. B.
1951. The role of exploratory fishing in the development of commercial fisheries. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3:* 95-105.

Springer, Stewart
1951. Operation of the exploratory fishing vessel "Oregon." Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3:* 79-80.
1951. The "Oregon" 's fishery explorations in the Gulf of Mexico, 1950. Commercial Fisheries Review, *13* (4): 1-8, figs. 1-5.

Whiteleather, R. T.
1951. How can the present research in exploratory fishing and fishing technology be most profitably expanded? Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3:* 140-142.

FISHERY INVESTIGATION

General, Stocks, Effects of Fishing

Baughman, J. L.
1951. Effect of the menhaden operations on other fisheries. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3*:80-85.

Brady, Winfield
1951. Report on spearfishing in Palm Beach County. Report for Florida State Board of Conservation.

Burkenroad, Martin D.
1951. Some principles of marine fishery biology. Publ. Inst. Mar. Sci., Texas, *2*(1):177-212.

The Marine Laboratory, University of Miami
1951. Quarterly reports on fisheries research for Florida State Board of Conservation. Mimeogr.

SHELLFISHERIES

Mollusca

Anderson, W. W. and Waldo L. Schmitt
1951. What are the most pressing requirements in research in inshore and shell fisheries? Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3*:136-138.

Grice, George D., Jr.
1951. Observations on Polydora (mudworm) in South Carolina waters. Contrib. No. 11, Bears Bluff Laboratories, 10 pp.

Gunter, Gordon
1951. The species of oysters of the Gulf, Caribbean, and West Indian region. Abstract. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3*:42. (also: Bull. Mar. Sci. Gulf & Caribbean, *1*(1):40-45.)
1951. The West Indian tree oyster on the Louisiana Coast, and notes on growth of the three Gulf Coast oysters. Science, *113*(2940):516-517.

Ingle, Robert M.
1951. Spawning and setting of oysters in Apalachicola Bay, Florida. Abstract. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3*:24.
1951. Spawning and setting of oysters in relation to seasonal environmental changes. Bull. Mar. Sci. Gulf & Caribbean, *1*(2):111-135.

Ingle, Robert M. and Charles E. Dawson, Jr.
1951. Variation in salinity and its relation to the Florida oyster. Salinity variations in Apalachicola Bay. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3*:35-42.

Lunz, G. Robert
1951. Laws for the oyster farmer. Contrib. No. 10, Bears Bluff Laboratories, 14 pp., 1 fig.

Mackin, J. G.
1951. Diseases of oysters and their relation to the Gulf coast oyster industry. Abstract. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3*:24. (also: Bull. Mar. Sci. Gulf & Caribbean, *1*(1):72-87.)

Crustacea

Broad, Carter
1951. Results of shrimp research in North Carolina. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3*:27-35.

Burkenroad, Martin D.
1951. Measurement of the natural growth rates of decapod crustaceans. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3*:25-26.

Chapman, W. M.
1951. International aspects of the shrimp fishery in the Gulf of Mexico. Abstract. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3*:52.

CHAUVIN, A. B.
1951. The outlook for continued shrimp production in Louisiana. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3:* 22-23.
DAWSON, CHARLES E., JR. AND CLARENCE P. IDYLL
1951. Investigations on the Florida spiny lobster, *Panulirus argus* (Latreille). Tech. Ser. No. 2, Florida State Board of Conservation.
GUNTER, GORDON
1951. Biological knowledge of shrimp. Seafood Business Mag., *3* (7): 8-10.
LEWIS, JOHN B.
1951. The Phyllosoma larvae of the spiny lobster, *Panulirus argus*. Bull. Mar. Sci. Gulf & Caribbean, *1* (2): 89-103.
LUNZ, G. ROBERT
1951. Investigations of trawling for crabs in inshore waters of South Carolina. Bears Bluff Laboratories. December.
LYLES, CHARLES H.
1951. The development of the brown shrimp fishery in Texas. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3:* 50-51.
SMITH, F. G. WALTON
1951. Caribbean spiny lobster investigations. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3:* 128-134.
SPRINGER, STEWART
1951. Expansion of Gulf of Mexico shrimp fishery, 1945-50. Commercial Fisheries Review, *13* (9): 1-6, figs. 1-5.
SWARTZ, MAX
1951. The outlook for shrimp production. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3:* 17.

OTHER PRODUCTS

HUMM, HAROLD J.
1951. Agar from *Digenea simplex*. In Florida State University Studies—Contributions to Science.
KAHN, RICHARD A.
1951. Is the natural sponge fishery doomed by synthetic sponges? Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3:* 43-49.
VINCENT, DANIEL B.
1951. Potentialities for increased utilization of scrap fish and fish waste in the Gulf and Caribbean area. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3:* 52-55.

SPECIAL PROBLEMS

Deterioration, Fouling, Boring

THE MARINE LABORATORY, UNIVERSITY OF MIAMI
1951. Marine borer investigation. Periodic Prog. Rep. Office of Naval Research.

MISCELLANEOUS

General

GALTSOFF, PAUL S.
1951. A survey of the present knowledge of the Gulf of Mexico: A progress report. Abstract. Proc. Gulf & Caribbean Fish. Inst., 3rd Annual Session, *3:* 127.
LEIPPER, DALE F.
1951. Oceanography and the Special Library. Contribution, Department of Oceanography, Texas A. & M. College, No. 13; Bulletin Special Libraries Association, Texas Chapter, October.

Instructions for Preparation of Manuscripts

CONTRIBUTIONS will be considered which deal with research in the marine sciences, directly or indirectly related to the southeastern United States and the Caribbean area. Papers dealing solely with the economic or applied aspects of commercial fisheries will not be accepted.

Manuscripts may be submitted in languages other than English but publication will be in English only. Where possible, arrangements will be made for translation.

All copy should be typewritten and double spaced. Footnotes should be avoided as far as possible. If used they should be numbered continuously throughout the paper and set off in the body of the text.

Bibliographical references must be indicated by author's name and year of publication. References should be listed under that heading in alphabetical order of authors. Each reference should include the last name followed by initials or the first name. Co-authors should be listed with initials preceding the last name. The date should appear next to the author's name, followed by a complete title, in lower case except for the first word. The publisher, city and pagination should follow, in the case of books. The names of periodicals should be abbreviated as in "World List of Scientific Periodicals," Oxford. The volume is then given in arabic numerals underlined for italics, followed by the number in brackets and the pagination preceded by a colon. After the first line of each reference the copy is indented.

Figures must be submitted with the manuscript, either as originals or photographs. Half-tone reproductions should be avoided where possible. Large numbers of tables or illustrations will usually be accepted only if arrangements are made by the author or his institution to contribute towards the cost. The proper size of lines, characters and symbols must be used and illustrations must be of such a size that they may be reduced by at least 2/3. Mechanical lettering should be employed. Alternatively, lettering may be indicated on a translucent paper cover, for setting by the editorial office. Tables should be simple and with a minimum of rulings. Legends should be typed on a separate sheet with proper identification by illustration number at the end of the manuscript. A brief abstract should accompany each contribution.

Articles may bear a contribution number from the institution responsible. This number should be submitted when returning the galley proofs if approved by that institution.

Fifty reprints only will be provided free for each paper. Additional reprints must be ordered when galley proofs are returned.

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